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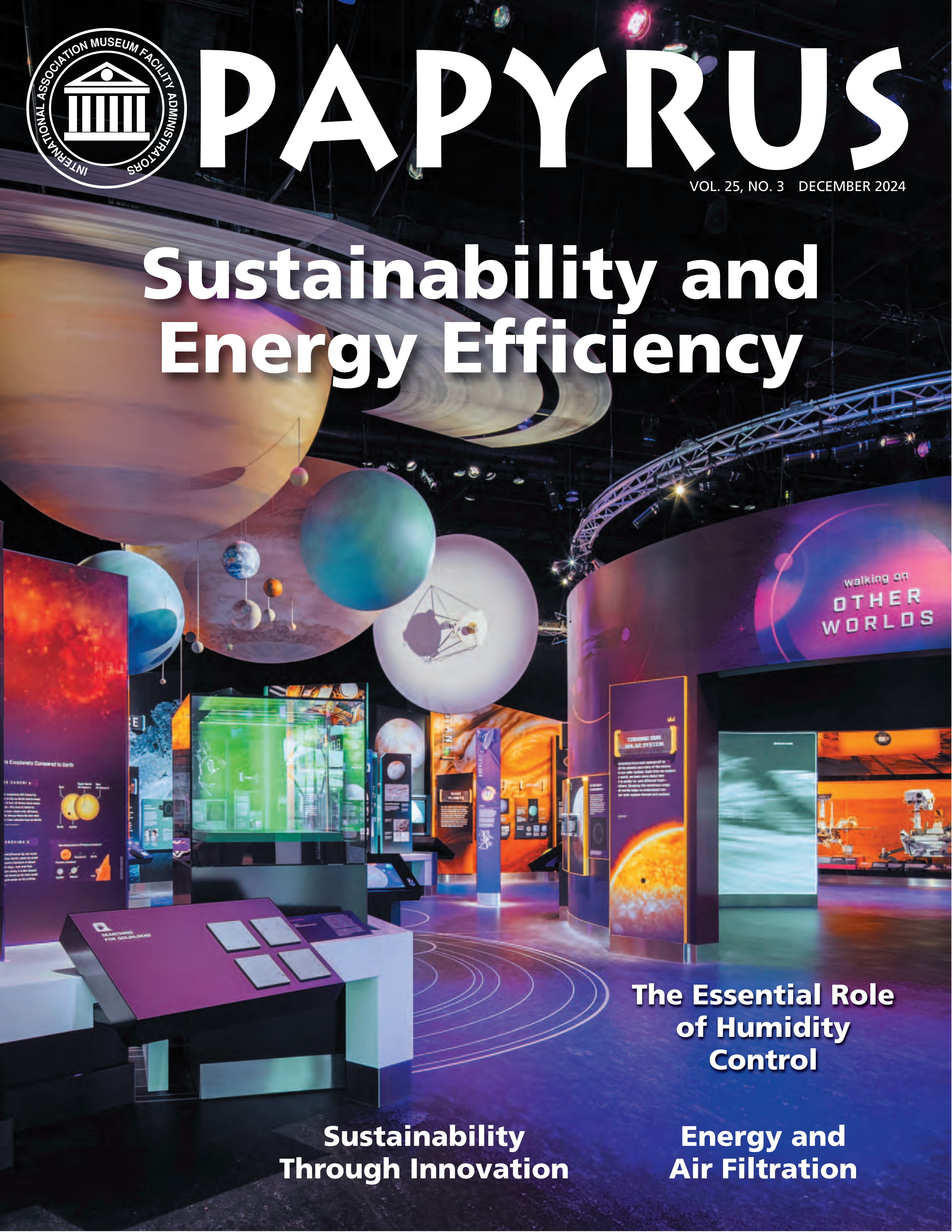

Sustainability and Energy Efficiency

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Achieving Sustainability Through Innovation

Modernization of the National Air and Space Museum

By Todd Garing and Rebecca Fischer

The modernization of the Smithsonian's National Air and Space Museum demonstrates how cultural institutions can dramatically improve energy efficiency while maintaining strict environmental controls for collections. The 687,000-square-foot museum, which welcomes more than seven million visitors annually, presented unique challenges in balancing sustainability goals with artifact preservation requirements. Through innovative engineering solutions and extensive modeling, the project expects a 47% reduction in site energy use intensity (EUI) compared to benchmarking data while tracking LEED Gold certification.

Addressing Four Decades of Operational Challenges

When the museum opened in 1976 as part of the nation's bicentennial celebration, it represented the state of the art in museum design. However, after four decades of continuous operation, several critical issues emerged. The building's envelope suffered from deterioration that hindered proper humidification, creating preservation challenges for the museum's irreplaceable artifacts. The original system design struggled with condensation issues, and excessive light penetration through skylights threatened sensitive materials. Additionally, leaking pipes, inconsistent temperature and humidity control, and limited accessibility, affected both operations and the visitor experience.

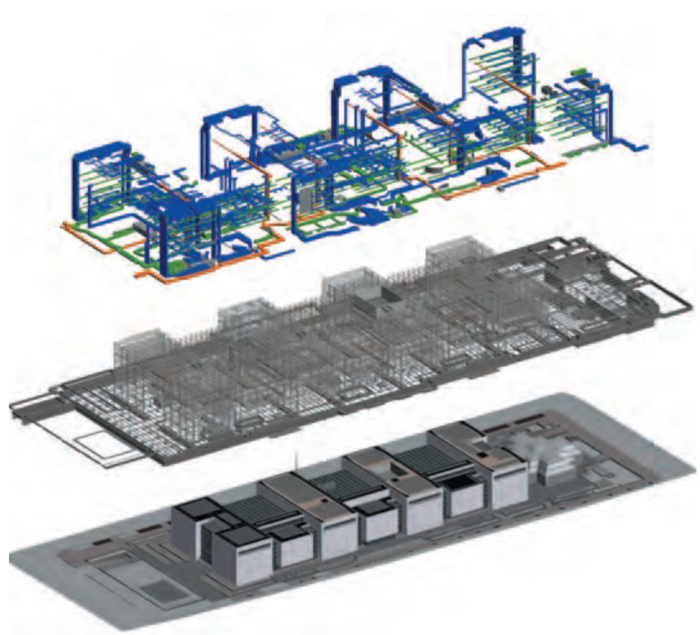
The Smithsonian Institution recognized that addressing these challenges required more than simple replacements—it demanded a comprehensive approach that would enhance sustainability while ensuring proper artifact preservation. The modernization goals included improving energy efficiency, implementing advanced control systems, enhancing visitor comfort, and creating a model for future Smithsonian renovations.

Modeling Excellence: Data-Driven Design Decisions

The design team, led by Quinn Evans as the architects and Mueller Associates as the MEP engineers, employed unprecedented modeling tools to inform architectural and mechanical system decisions. A comprehensive Revit® building information model (BIM) served as the foundation, providing detailed documentation of spaces, equipment, and finishes that will continue to serve as a facility management tool well into the future.

Energy modeling proved particularly crucial in identifying opportunities for efficiency gains. The models demonstrated that allowing limited seasonal variation in space temperature and relative humidity would contribute nearly 20% in energy savings—the single most significant contributor to reduced energy consumption. The second-largest contributor came from implementing LED lighting with daylight sensors, highlighting how multiple systems working in concert could achieve substantial results.

The team utilized WUFI (heat and moisture transiency) modeling to evaluate vapor diffusion and moisture transport in building materials. This analysis proved essential in understanding how the building envelope would perform under various conditions. Complementing this, THERM modeling assessed two-dimensional heat transfer effects in building components such as glass curtain walls and stone-clad walls. These models informed crucial decisions about insulation placement and the selection of glazing and frames for curtain walls and skylights.



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Building Information Model (BIM) of the National Air and Space Museum's integrated mechanical, electrical, and plumbing systems. The comprehensive 3D model helped optimize system placement within the building's complex architecture while ensuring maximum efficiency and minimal interference with gallery spaces.

Computational fluid dynamics (CFD) modeling was vital in optimizing the building's thermal environment. The museum's unique architecture, featuring artifacts suspended at varying heights in 60-foot-tall skylit atrium galleries, created challenges for air distribution. CFD modeling helped identify optimal locations for air diffusers, and revealed solutions for preventing condensation through strategically placing radiators along floors and walls.

Engineering Innovation: Next-Generation Building Systems

The project implements several pioneering approaches to heating and cooling, which demonstrates how cultural institutions can move beyond traditional solutions. A hybrid approach that enhances efficiency and resilience has significantly reduced previous reliance on the U.S. General Services Administration's (GSA) chilled-water and steam systems.

At the heart of the heating system, new Fulton condensing hot water natural-gas-fired boilers provide complete heating capacity with N+1 redundancy, eliminating dependence on GSA steam. The system's efficiency is so significant that it's projected to pay for itself in less than two years—a compelling proof point for institutions considering similar upgrades.

The cooling plant exemplifies innovative thinking in system design. While the onsite chiller plant capacity is only 50% of peak load, it provides more than 80% of annual chilled water capacity through a combination of a Trane variable-speed, high-efficiency centrifugal chiller, and a dedicated heat-recovery rotary chiller. GSA chilled-water service provides peak capacity only when needed, optimizing the system's efficiency and cost-effectiveness.

The dedicated heat-recovery chiller (DHRC) stands out as a particularly smart solution. It addresses four distinct challenges:

1. eliminating boiler operation during the summer heat,
2. removing GSA chilled water needed during winter cooling,
3. providing supplemental winter heating, and
4. delivering supplemental summer cooling.

This multifunctional approach significantly reduces carbon emissions while improving operational efficiency. Perhaps most significantly, the DHRC provides 85% of the heating energy annually, drastically limiting the use of natural gas.

Air distribution received equally careful attention. The galleries utilize a high-performance variable-air-volume (HPVAV) system featuring dedicated outdoor air-system (DOAS) pretreatment, air-side enthalpy energy recovery, adiabatic humidification, and MERV-15 filtration. The DOAS effectively manages gallery dehumidification loads, allowing air-handling units to reset supply-air temperature based on sensible cooling loads, substantially reducing reheat requirements.

Sustainable Water Systems: From Roof to Reuse

The museum's water conservation approach demonstrates how large cultural institutions can significantly reduce potable water consumption. The centerpiece of this strategy is a rainwater harvesting system that takes advantage of the building's nearly four acres of roof and terrace areas—approximately 165,000 square feet of collection surface.

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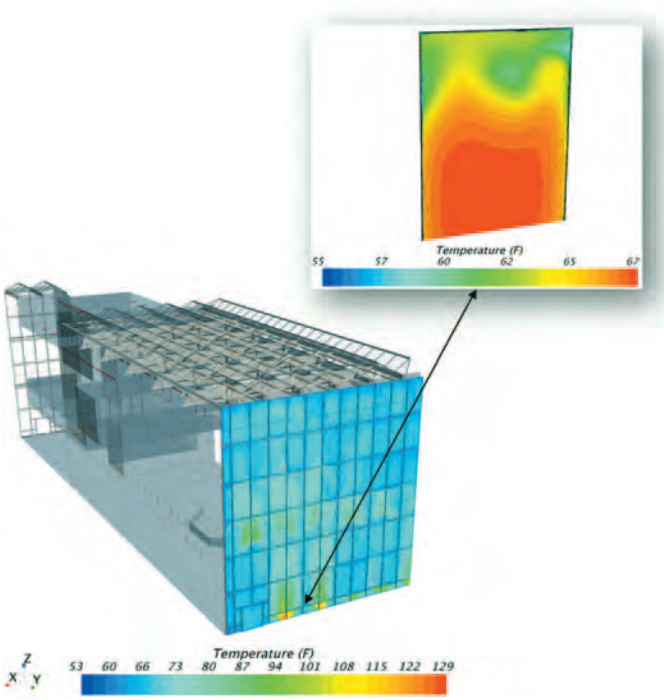

THERM modeling assessed two-dimensional heat transfer effects in building components such as glass curtain and stone-clad walls

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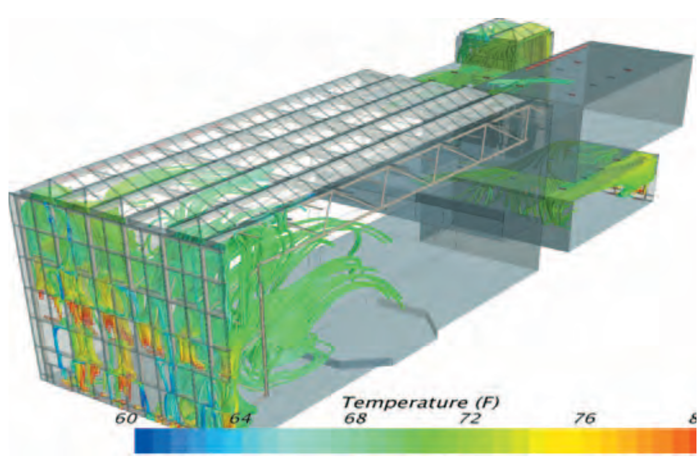

With 60-foot atrium galleries featuring artifacts suspended at varying heights, CFD models assessed the need for air stratification—providing thermal comfort for visitors and optimal environmental conditions for the artifacts at the different levels.

Two 100,000-gallon concrete cisterns, located at the east and west ends of the building, collect an estimated 4.4 million gallons of rainwater annually. This harvested water serves multiple purposes: irrigation, cooling tower makeup water, and toilet and urinal flushing. The system's implementation required careful coordination among disciplines, particularly in routing roof and skylight drains and air-conditioning condensate to the harvesting system.

The water-conservation infrastructure is impressive in scope, with more than 20 miles of new plumbing piping installed throughout the building. This includes the rainwater-harvesting gravity-drain system, filtered non-potable water distribution, domestic hot- and cold-water systems, and complete sanitary and vent systems. The system features duplex pumps, four 1,500-gallon day tanks, and sophisticated filtration and U.V. treatment systems to ensure water quality for various uses.

Smart Building Intelligence

The building automation system (BAS) represents a significant advance in building control technology. The system implements sophisticated demand-based controls that continuously monitor multiple building parameters: space CO_2 levels, chilled and heating water pressure, pressure-independent control valve positions, differential pressures, damper positions, space conditions, and airflow metrics.

Siemens demand-based controls constantly analyze these inputs to reset equipment setpoints and deliver only the energy required to satisfy actual demand. This approach optimizes energy efficiency and helps maintain precise environmental conditions for artifact preservation.

Smart Illumination and Envelope Enhancement

The modernization includes a complete overhaul of the lighting system, transitioning to LED fixtures with daylight sensors. This upgrade reduces energy consumption and provides better control over light levels for artifact preservation. A daylighting model, which assessed light exposure at different times of the year, helped the team devise a protection strategy combining tinted fritted glass and interior shading devices.

The building envelope improvements demonstrate how modern materials and techniques can enhance energy efficiency and artifact preservation. The team's detailed analysis led to solutions maintaining the building's historical character while providing better thermal performance and condensation control.

The "Triple Win": Lessons for Cultural Institutions

The modernization achieves multiple sustainability benchmarks: a 47% reduction in site EUI compared to benchmarks and a 38% reduction in greenhouse gas emissions. The project is also on track to earn LEED Gold certification. These results stem from carefully integrating multiple systems and strategies, each contributing to overall improvements in performance.

Furthermore, the Smithsonian has begun incorporating this project's design elements to pilot future renovations across 19 museums and nine research centers. The successful integration of energy efficiency, collections care, and visitor comfort demonstrates how cultural institutions can achieve what

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The galleries' sophisticated air-distribution system combines high-performance VAV with dedicated outdoor-air pretreatment, energy recovery, adiabatic humidification, and MERV-15 filtration. This allows precise dehumidification control while minimizing reheat energy through optimized supply-air temperature reset strategies.

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The museum's lighting modernization features LED fixtures with daylight sensors, paired with tinted fritted glass and interior shading devices. This comprehensive strategy was developed using daylighting models to reduce energy consumption, while also ensuring precise control over light levels for artifact preservation.

our team calls the "triple win": protecting artifacts, reducing energy consumption, and maintaining visitor comfort.

This project emphasizes the importance of comprehensive modeling in informing decision-making for facility administrators considering similar modernizations. The success of hybrid approaches to traditional building systems and solutions that address multiple challenges simultaneously provides a valuable roadmap for other institutions. Most importantly, the project proves that stringent collections-care requirements need not conflict with ambitious energy-efficiency goals.

Timeline to Tomorrow: Completing the Vision

The first phase of this ambitious modernization project reached a significant milestone in October 2022, with the reopening of the museum's west end. This initial phase demonstrated the first phase in the successful implementation of the innovative systems described above. Visitors to the renewed spaces have already experienced the benefits of improved climate control and lighting. At the same time, behind the scenes, the new mechanical systems have proven their efficiency in real-world operations.

Work continues on the east end of the building for the project's completion in 2025, and the grand reopening planned for 2026. This timing carries special significance, as it will coincide with both the museum's 50th anniversary and the United States' 250th anniversary. Just as the museum's original opening marked Bicentennial celebrations in 1976, its complete renewal will help usher in another national historical milestone.

The fully modernized museum will serve as a living testament to how cultural institutions can embrace sustainability while preserving our nation's treasures.

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The west wing's October 2022 reopening unveiled eight reimagined galleries—including "Destination Moon," "Nation of Speed," "America by Air," "Early Flight," "Wright Brothers & the Invention of the Aerial Age," "One World Connected," "Kenneth C. Griffin Exploring the Planets," and "Thomas W. Haas We All Fly." All featured state-of-the-art exhibits within spaces now optimized for both artifact preservation and visitor comfort through advanced environmental controls and lighting systems.