A low-energy, high-tech landmark laboratory

Inventive design in a complex location has transformed an underutilised section of the Carnegie Mellon University campus, creating a new home for high-tech research

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The Sherman and Joyce Bowie Scott Hall is located on a steep hillside site at the western end of the historic Hornbostel Mall on the Carnegie Mellon University campus in Pittsburgh. The university's initial plan involved constructing a seven-storey building, but when the project was put out for competition, OFFICE 52 Architecture had more ambitious ideas. It proposed a scheme that made the most of one of the last remaining free spaces on campus.

The plan envisioned expanding the site to include an adjacent, underutilised sunken service yard between three existing buildings (built in 1905, 1908 and 1968), and elevating the building at its north-west corner to span over a fire access road and underground campus utilities. The building would also project over the steeply sloping side of the Junction Hollow ravine. This replanning maximised the contiguous, same-floor programme area and allowed the connectivity of all the adjacent buildings. In addition, this new home for the College of Engineering needed to be a facility that would promote the collaborative nature of its high-tech research; the proposed scheme also fulfilled this brief. The plan prioritised green space and the importance of the Mall, transforming this part of the campus into an inviting and integrated outdoor space.

From the start of the competition, the design team of OFFICE 52, Arup (as multidisciplinary engineer) and Stantec (as executive architect) worked in close collaboration to overcome the considerable challenges of developing this highly constrained site. Arup's team provided structural, mechanical, electrical, plumbing and fire protection engineering; lighting/daylighting, acoustics and vibration, and code consulting; and ICT services.

Scott Hall

The 109,000ft² (10,000m²) building houses the Wilton E. Scott Institute for Energy Innovation, the Department of Biomedical Engineering, the Engineering Research Accelerator, the Disruptive Health Technologies Institute and the Bertucci Nanotechnology Laboratory.

The design team's proposal, which used the site's topography to its advantage, means that the facility consists of two distinct but connected parts. The North Wing, with four occupied floors, has a striking glazed high-performance façade and is dramatically elevated over the ravine. The Bertucci Nanotechnology Laboratory infills the service yard.

The common area that links the North Wing with the Bertucci Laboratory incorporates the light-filled Arthur C. Ruge Atrium, the café and the Collaboratory circulation space. It is designed to promote interaction and collaboration among the different departments, with flexible spaces for both formal and informal meetings. This area links all levels in the building, and provides direct connections to seven different floor levels in the three neighbouring buildings, greatly improving accessibility and connectivity across this area of the campus.

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1: The Sherman and Joyce Bowie Scott Hall building is designed to promote collaboration


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2: Part of the building is located on steeply sloping ground

3: The common areas that link the various parts of the building are open and spacious, to promote interdisciplinary cooperation

4: Vibration tests were undertaken to ensure the laboratory areas met the stringent vibration requirements

Sustainability goals
The initial project goal was to achieve LEED Silver certification. However, Arup's multidisciplinary engineering team had previously designed other buildings on the Carnegie Mellon campus, the Gates and Hillman Centers, which are LEED Gold-certified, and the team decided to aim for the same certification level for Scott Hall. Crucial in making the overall building as low-energy as possible was designing a highly efficient cleanroom.

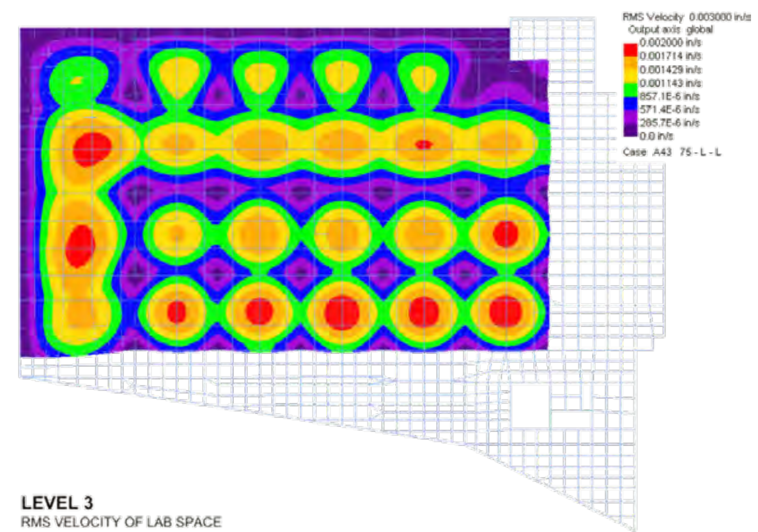
Vibration
The nanotechnology research carried out in Scott Hall is highly sensitive to vibration; a specific requirement for the design was that it had to meet up to vibration criterion (VC) E (the most stringent criterion) in the Bertucci Nanotechnology Laboratory. The North Wing laboratories and associated technical support areas needed to achieve VC-A across the entire floor area.

The site's many sources of vibration presented considerable challenges. These include an active rail freight line in Junction Hollow, less than 100ft (30m) from the building; an electrical substation with fans and transformers; and chillers and pumps in tunnels running below part of the cleanroom.

Arup's acoustics engineers carried out detailed vibration surveys during the scheme design stage and monitored levels during construction to determine ambient site vibrations. The survey included surface and borehole measurements to 50ft (15m) below ground. Accelerometers were used to record vibration levels vertically and horizontally, in two directions, at several important locations, including close to the planned location of the vibration-sensitive equipment in the cleanroom.

Subsequent analysis of the data gathered, along with further feasibility studies, confirmed that placing the cleanroom and VC-E areas, the vital core of the nanotechnology laboratory, in the old service yard would mean the vibration criteria could be met. This location, being furthest from the rail line and having the advantage of the laboratories being built on grade – rather than elevated floor slabs – significantly improved the vibration environment, thereby reducing construction complexity and costs. An 18in (457mm) deep ground-bearing slab achieves VC-E and VC-D based on recorded ambient site vibrations, and performs to VC-D for footfall-induced vibrations.

Laboratory systems
Accurate regulation of temperature and humidity is essential to the research carried out in the 11,000ft² (1,000m²) cleanrooms and the surrounding research spaces, and the class 10/100 cleanrooms require high air change rates. The process systems and the high-tech tools used in the laboratory mean there is a substantial cooling load and, owing to the 24/7 operation of the spaces, continuous cooling capability is needed. Although the cleanroom is only 13% of Scott Hall's area, energy modelling showed it accounted for approximately 50% of the building's overall energy use. It was essential



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that the systems minimised energy usage as far as possible. Arup's design incorporated cost-effective, low-energy measures, including energy recovery systems, cascaded water loops to increase the temperature difference between the supply and return water temperatures, limited humidification, variable laboratory air change rates and reductions in lighting power density. The greatest efficiencies were achieved by improving fan performance and, using occupancy sensors, allowing a setback condition when spaces are vacant.

Working closely with cleanroom designer Jacobs, Arup designed the essential building services for the facility. These included chilled water, power and controls, and the exhaust and make-up air controls. The design controls the regular extraction of hazardous gases from the space. The air management system provides temperature stability across the cleanroom of ± 0.5°F and humidity within ± 2% relative humidity, with the clean bays certified at rest as meeting the ISO 14644 Class 1 standard.

The energy performance for the cleanroom is 9,960 cu ft/min/kW.

Arup also worked with the university's Environmental Health and Safety Department on the design for management of hazardous gases and fire alarm operations for the pyrophoric and toxic gases that are used in the cleanroom.

Isolation requirements for the mechanical and electrical equipment within the building were specified by Arup. In collaboration with the electro-acoustic consultant, the firm ensured no stray electromagnetic interferences were created by the electrical infrastructure.

Green roof
The Bertucci lab consists of a concrete frame with 24in (610mm) square columns on a 30ft x 23ft (9m x 7m) grid supporting a 15in (381mm) thick concrete flat slab at Mall level. On top of the slab is a green roof, which not only provides new public green space and connections to the rest of the campus, but also contributes to stormwater management, reducing rainwater run-off by 20% compared with pre-development levels.

Approximately half of Scott Hall's total roof area is a vegetated green roof, planted with lawn and native species that do not require irrigation. Over 85% of suspended solid pollutants are filtered out of the stormwater via the roof; previously the area was tarmac, so all the stormwater went straight into the surface water collection system.

The green roof means that the temperature in the laboratories is better modulated, as the

5: The varying vibration levels were mapped across the laboratory area

6: The laboratories were designed to be easily adaptable for future changes, with capacity for additional power, heating and cooling

7: Internal windows provide views into the laboratory areas


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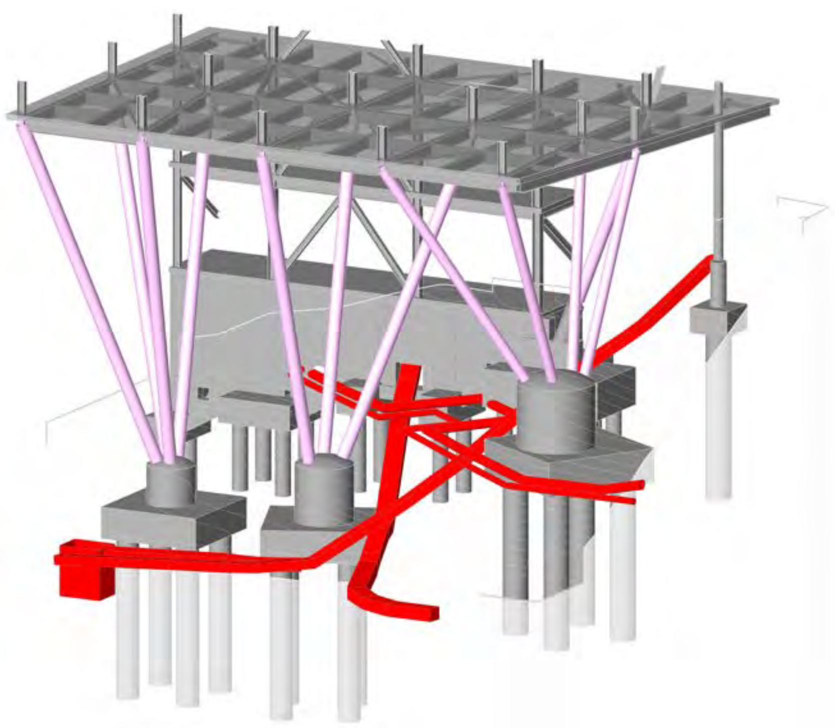

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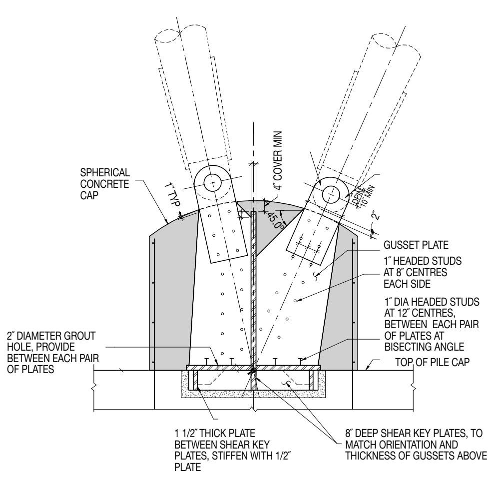
vegetation protects the space from overheating in summer and provides more insulation in winter. In addition, the roof's skylights allow daylight to be introduced to interior circulation spaces.

North Wing building services systems

Separate building services systems serve the Bertucci lab and North Wing almost independently, reflecting the differing requirements of both spaces, the overall length of the building, the site geometry and the proximity to existing systems in other buildings. This separation also means the systems' distribution costs were minimised.



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A combined manifold air handling unit (AHU) serving the majority of the North Wing allows for substantial turndown when demand is low, without sacrificing temperature performance. Lead-lag laboratory exhaust fans at the roof are matched to the AHU and provide the requisite stack velocity to minimise re-entrainment of the expelled fumes and chemicals. An energy recovery loop between the AHU and exhaust fans reduces energy demand.

In addition to energy efficiency, building services systems in the North Wing have been designed for future flexibility. They can be expanded for power, heating and cooling if required as the research process evolves. Additional capacity is included in the process chilled water system and house systems such as nitrogen dioxide and compressed air distribution. Sections of the laboratory floors are designed to be converted readily to either wet or dry laboratory spaces.

There are two levels of mechanical and electrical plant areas in the North Wing. These are set back into the hill at the lowest levels, beneath the occupied floors. The lowest level is the main 5kV electrical room, which has step-down transformers sized to accommodate future additional power demand.

8: Model of the building's foundations and pre-existing services

9: The steel frame of the North Wing projects out over the hillside, supported by diagonal structural columns

10: The façade reflects and refracts light differently throughout the day, meaning that the building's appearance is constantly changing

Sloping column support

There were many structural design challenges at this part of the site, including poor soil conditions; the need to span the existing fire access road; and accommodating extensive existing underground services such as the campus's primary steam loop, a main electrical supply and surface water drainage. The North Wing steel frame structure projects prominently out over the hillside of Junction Hollow and is supported by diagonal structural columns – an arrangement used to minimise the disturbance to the existing campus services. A steel-braced frame provides lateral stability for the building. The structural grid is typically 21ft x 21ft (6.4m x 6.4m), but with storey-deep transfer structures in a number of locations to allow the building to span the fire access road.

The building and existing site services were modelled in Revit for all disciplines to help with coordination. The model was also used to map the existing sub-grade services, with the foundations and sloping columns strategically located to avoid disturbing these critical campus services where possible. Excavated field conditions and poor soil capacities required relocation of some of these services and some temporary support during construction, further complicating the construction in an already congested area.

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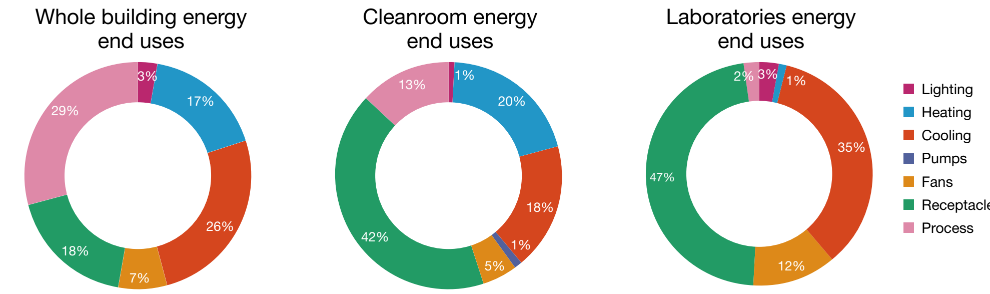
High-performance envelope

The orientation of the North Wing, which is aligned with the Wean Hall and Hornbostel Mall, maximises the amount of daylight it receives. An iterative process between OFFICE 52 and Arup to determine transparency and shading allowed for flexibility in the aesthetic approach while limiting the amount of energy required for space conditioning. Solar penetration studies, thermal comfort analysis and energy modelling were used to arrive at the optimum arrangement of façade elements.

For the Collaboratory, which features a glazed atrium and glazed walls, ceramic frit on the glazing was combined with a system of external fins, brise-soleil and internal solar shades to address occupant comfort, thermal loads and glare. Dichroic glass, created with technology commonplace in nano-scale research, is used for these external fins. The frit design is an abstraction of a photonic quasi-crystal structure, which creates a geometric pattern that brings together art, design, technology and science within the architecture. The façade's ever-changing reflections and refractions transform the building's appearance depending on the time of day, the season and the intensity of light.



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This careful selection of the glazing and shading, coupled with daylight dimming and occupancy sensors, created further energy reductions in the lighting system. Low lighting power densities and a mixture of general and task lighting are used.

Sustainable laboratory building

By embracing the local topography and focusing on energy efficiency, the design of Scott Hall has provided a flexible and sustainable laboratory facility for Carnegie Mellon University. The project received a Silver award in the building/technology systems category at the 2018 American Council of Engineering Companies Excellence Awards. The building was awarded LEED Gold certification status in recognition of its low energy use and high sustainability credentials – quite an achievement for such a heavily serviced building that includes cleanrooms with strict temperature regulation.

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11: Minimising and managing energy usage in the building was key to attaining LEED Gold certification for the facility

12: The Scott Hall building has transformed a once-neglected part of Carnegie Mellon University

Authors

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Project credits

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Laboratory planning and cleanroom consultant Jacobs
Construction manager and general contractor Jendoco Construction Corporation
Structural engineering, building services, code, lighting/daylighting, vibration and acoustical consulting Arup:
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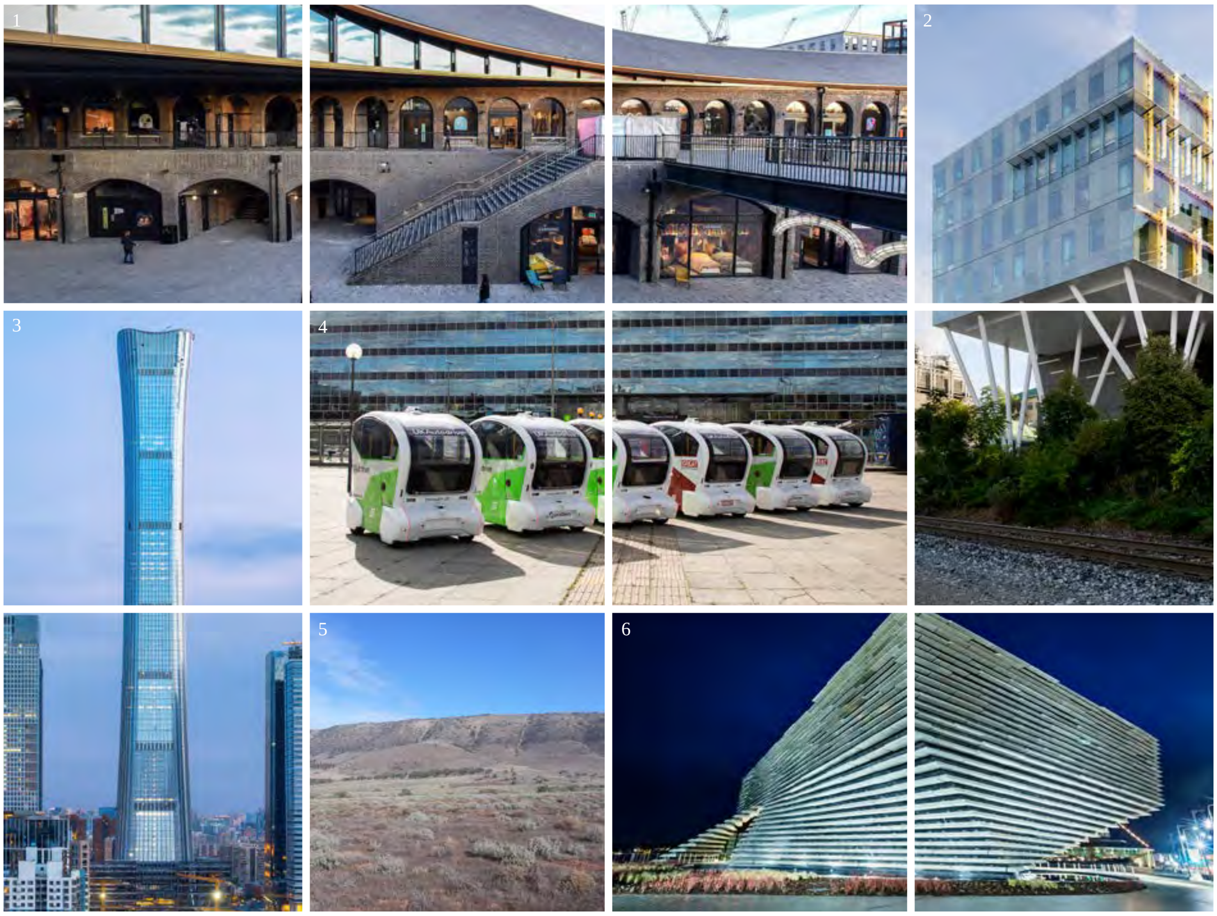

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