# DAYLIGHTING THE NEW YORK TIMES HEADQUARTERS BUILDING

Final Report

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**ABSTRACT**

The technical energy-savings potential for smart integrated window-daylighting systems is excellent and can yield significant reductions in US commercial building energy use if adopted by a significant percentage of the market. However, conventional automated shades and daylighting controls have been commercially available for over two decades with less than 1-2% market penetration in the US. As with all innovations, the problem with accelerating market adoption is one of decreasing risk. As the building owner researches technology options, the usual questions surface that concern the purchase of any new product: how will it work for my application, are the vendor claims valid, what risks are incurred, and will the performance benefits be sustained over the life of the installation? In their effort to create an environment that "enhances the way we work" in their new 139 $km^2$ (1.5 $Mft^2$) headquarters building in downtown Manhattan, The New York Times employed a unique approach to create a competitive marketplace for daylighting systems. A monitored field test formed the strategic cornerstone for accelerating an industry response to the building owners' challenge to a sleepy market (i.e., US automated shading and daylighting control products have had few major technical advances over the past 10 years). Energy, control system, and environmental quality performance of commercially-available automated roller shade and daylighting control systems were evaluated. Procurement specifications were produced. Bids were received that met The Times cost-effective criteria. The Times will proceed with the use of these systems in their final building. Competitively-priced new products have been developed as a result of this research and are now available on the market.



Key words:

Daylighting, automated window shades, automated daylighting controls, energy-efficiency, visual comfort.

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# SUMMARY

The technical energy-savings potential for smart integrated window-daylighting systems is promising and can yield significant reductions in New York commercial building energy use and electrical demand if adopted by a significant percentage of the market. However, although conventional automated shades and daylighting controls have been commercially available for over two decades, they have achieved less than 1-2% market penetration in the US. As with all innovations, the problem with accelerating market adoption of new technologies and systems is one of decreasing cost and risk. As the building owner researches technology and system options, the usual questions surface that concern the purchase of any new product or system: how will it work for my application, are the vendor claims valid, what risks are incurred, how do I integrate all the system elements, and will the performance benefits be sustained over the life of the installation?

In their effort to create an environment that "enhances the way we work" in their new 139,000 $m^2$ (1.5 $Mft^2$) headquarters building in downtown Manhattan, The New York Times employed a unique approach to create a competitive marketplace for daylighting systems and to understand and reduce the risks associated with innovative technologies. A monitored field test in a 401 $m^2$ (4318 $ft^2$) daylighting mockup formed the strategic cornerstone for accelerating an industry response to the building owners' challenge to a sleepy market. Energy, control system, and environmental quality performance of several commercially-available automated roller shade and daylighting control systems were evaluated in the daylighting mockup from solstice to solstice for six months. Procurement specifications were then produced as a result of the lessons learned by The Times at the daylighting mockup. Competitive bids were received that met The Times' cost-effective criteria. The Times is proceeding with the use of these systems in their building, now under construction. New competitively priced systems with improved performance capabilities have been developed as a result of this research and are now available on the market.

This report provides a detailed third-party assessment of the performance of these systems under real sun and sky conditions over a nine-month test period. Supplementary Radiance visualization simulations were used to explore alternate design options. An occupant survey was also administered at the daylighting mockup to 53 office workers to evaluate their subjective appraisal of the quality of the interior environment. These data were presented at interim stages to the building owner and were used to provide feedback to the industry partners who were demonstrating their systems in the daylighting mockup. The system design and functionality evolved to address problems that arose in the field or to add new features that would enhance user acceptance or the quality of the interior environment. After the completion of the six-month study, the vendors were encouraged to continue testing and developing their systems for an

additional three months prior to selection of the final manufacturers via a competitive performance specification.

Two types of daylighting control systems were installed: one in the north zone of the daylighting mockup (Area A) which was daylit primarily by west facing windows and one in the south zone (Area B) which was daylit by both west-facing and south-facing windows. Both systems provided continuous dimming of T8 lamps (T5 lamps were later specified) over a 35-100% power range. The lights were switched off if there was sufficient daylight to meet the design setpoint of 510 lux. Due to the unique façade design with partial exterior shading, transparent floor-to-ceiling clear glass (visible transmittance was 0.75), and low-height interior furnishings, average daily lighting energy savings in Area A were 30% at 3.35 m (11 ft) from the window and 5-10% at 4.57-9.14 m (15-25 ft) from the window compared to a non-daylit reference case. In Area B, these savings were 50-60% and 25-40% for the same distances, respectively, given a bilateral daylit condition. HVAC energy use was not monitored or simulated – the focus of the monitoring was on lighting energy use savings due to the complexities of accurately monitoring thermal loads given an innovative underfloor-air distribution system.[1] Both lighting systems, after some period of commissioning, performed reliably: work plane illuminance levels were maintained above 90% of the maximum fluorescent illuminance level for 100% and 98% of the day on average in Areas A and B, respectively. The DALI-EIB protocol control system in Area B exhibited faulty behavior (erratic on, off, or loss of proper zone assignment throughout the test period) that remains unexplained.

Two types of automated roller shades were installed. Both systems met their respective design intent expectations. In Area A, the shade control system was designed to balance window glare, daylight, and view requirements and was able to deliver a tunable system that satisfied the building owner's desire for daylight, a bright interior, and view while addressing window glare. The dc motorized operations were quiet, smooth and provided accurate lower edge alignment over the nine-month test period in Area A. In Area B, the shade control system was designed to block direct sun penetration to a specified depth from the window wall and accomplished this goal well throughout the duration of the test. In the latter three-month test period, Area B's manufacturer began development of new control algorithms to control window brightness and results of this development work are included in this report. The ac-motorized operations exhibited more mechanical problems initially due to improper installation of the system at the ceiling header – these were explained and fixed in short order. Neither system exhibited undesirable control hysteresis. Both systems will require further work to better address visual comfort requirements.

[1] Despite the floor-to-ceiling windows, the effective solar heat gain coefficient (SHGC) of the façade system was competitive with smaller sized windows. The center-of-glass SHGC of the spectrally-selective low-e insulating glass units was 0.39. With the exterior shading provided by the ceramic tubes and the reliable control of direct sun by the interior shades, the effective SHGC of the façade was significantly less than 0.39.

The visual environment was evaluated in detail in terms of lighting quantity and quality. For the main viewing direction toward the east (facing away from the window) in Area A, occupants will be visually comfortable performing computer-based visual display terminal (VDT) tasks for the majority of the day throughout the year, particularly if the shades are controlled for glare. The new commercially available low-reflectance, high-brightness liquid crystal display (LCD) flat-screen monitors were used in this evaluation. The average west window luminance was consistently maintained below 2000 cd/$m^2$ by the automated shade control for the majority of the day (maximum of 54 min in a day when this limit was exceeded). With the shade operating, average daily total (daylight + electric light) illuminance levels were within ~800-1200 lux at a distance of 3.35 m (11 ft) from the window wall. Unobstructed outdoor view (i.e., shade retracted above vision level) was available for at least 65% of the day. With Area B's control strategy of limiting direct sun penetration to 0.91 m (3 ft) from the window wall, the performance in Area B on the west façade was nearly comparable to that in Area A. Luminance ratios were maintained to acceptable levels for the majority of the day throughout the year for the east viewing direction and for tasks involving the VDT. The average west window wall luminance was maintained below 2000 cd/$m^2$ for the majority of the period (maximum of 71 min in a day when this limit was exceeded). View was available for at least 75% of the day.

In the south zone within Area B with the strategy of limiting direct sun penetration, the shading system did not provide consistently acceptable comfort conditions. This was due primarily to the lack of shade closure when the south window wall luminance levels were high even when there was no direct sun. Occupants performing VDT tasks with the south window in the field of view will experience glare because the luminance ratio limit of 1:10 between the VDT and south window was exceeded for a significant percentage of the day (>40% of the day throughout the monitored period). South window luminance levels exceeded 2000 cd/$m^2$ for the majority of the day (>200 minutes per day). Direct sun and glare control is clearly needed on the south façade to achieve comfortable conditions. In both Areas A and B, the direct orb of the sun will cause visual discomfort and disability glare when directly viewed by the occupant even when the 3%-open fabric roller shade is down.

The findings derived from the monitored data were supported by the subjective appraisals conducted on 53 subjects. With automated control, glare from windows reached the "uncomfortable" level when luminances in the space became high. Monitored data showed that the occupants manually overrode the control system to lower the shade a significant fraction (30%) of the time. This was much more likely to occur at relatively low exterior light levels than at high exterior light levels. It was also far more likely to occur when people spent a significant fraction of their time in meetings in the open plan area. There was a distinct trend for increased glare from electric lights for work stations farthest from the west window. There was a noticeable increase in difficulty in reading computer screens adjacent to the window, and, consistent with the trend in glare from electric lighting, farthest from the window. The problem nearest the window is presumably due to glare from the windows themselves, while the problem in readability farthest from the windows is presumably due to glare from the electric lighting. A higher density shade and modifications to the control algorithm were recommended.

A second phase of work was conducted in order to provide timely engineering data to the selected manufacturers. Radiance visualization simulations were conducted on typical floors of the Headquarters building in its urban context and data resulting from these simulations were used to assist with specifying fabric type, photosensor locations, and shading and lighting control zones on the shop drawings that were issued in the Spring of 2005. Shadow studies provided detailed information on how the complex urban obstructions surrounding the 52-story tower and podium would shade the various facades of the new building at different floor levels. This information was used to define shade and lighting control zones. Illuminance data were provided to give the lighting controls manufacturer an idea of how the distribution of daylight across typical floors of the headquarters tower changed over the course of typical solstice and equinox days. Photosensor and desk illuminance data were also provided to help the manufacturer characterize the correlations between the ceiling-mounted photosensor response and work plane illuminance thus optimizing sensor placement and zoning. Time-lapse images were produced to help the building owner and manufacturers understand the visual comfort and quality of the space from various viewpoints. Annualized Radiance simulations were also conducted to quantify window luminance and illuminance frequencies resulting from various control algorithms. This information was used by the manufacturer and building owner to assist in making their fabric selection for various facades and floors of the new building.

Over 600 architects, engineers and building owners toured the mockup and were able to experience the integrated daylighting solution. Broader outreach to the New York A/E community was made via a comprehensive project website, presentations at Lightfair and press articles. The performance specifications were published to assist other New York owners in following the pathway set by the Times. Even in this early phase of the work the project has stimulated new interest in these daylighting solutions and their potential for energy savings and demand reductions in New York buildings. An additional phase of work is planned that will develop commissioning procedures for automated shade and daylighting control systems in the newly constructed building.

# Section 1
# INTRODUCTION

Energy use in commercial buildings continues to grow despite progress with improved building technologies, voluntary efficiency programs and more stringent building codes. Electricity use and electric demand are critical national and state issues, and can be particularly important in specific areas such as New York City where the ability to provide new power generating capacity to meet growing demand is limited. Energy efficiency and demand reduction strategies that reduce end use requirements are both important elements in New York State's efforts to maintain reliability of the electric grid and reduce customer bills for electricity. Within commercial buildings, electric lighting and cooling represent two of the largest electric end uses. Strategies that reduce these end uses will thus provide benefits to building owners and to State efforts to provide reliable supplies. Daylighting strategies that manage solar gain and glare while providing adequate interior daylight to dim or turn off electric lighting are thus key approaches to reducing lighting and cooling loads. These strategies must be carefully integrated so that both cooling and lighting are minimized. Furthermore they must be designed and implemented in a manner that is affordable to the owners and provides reliable long term benefits in order for owners to make the required initial investments. Daylighting strategies in the form of dynamic envelope and lighting systems can provide the needed savings but these systems are rarely specified and used today for a number of reasons. Research studies in the recent past have established the technical capabilities of these systems but many practical obstacles remain slowing widespread adoption and routine use of these approaches.

The Lawrence Berkeley National Laboratory (LBNL) has been advocating dynamic envelope and lighting systems over the past decade. In a four-year project supported by the California Institute for Energy Efficiency, automated Venetian blinds and daylighting controls were integrated together to form an integrated dynamic system. This system was an off-the-shelf precursor to the switchable electrochromic windows under laboratory development at the time and allowed us to play with proof-of-concept prototypes, test its performance under real sun and sky conditions, and evaluate its energy savings potential as well occupant acceptance and satisfaction with the technology and resultant environment [Lee et al. 1998]. Recently, LBNL progressed to similar field tests using large-area electrochromic windows with daylighting controls to prove similar concepts and performance [Lee et al. 2006]. These smart window and lighting systems may advance us toward the goal of net zero energy buildings through real time management of solar heat gains and daylight. The systems also enable building owners to achieve flexible real-time load management of two of the largest end uses in commercial buildings, air-conditioning and lighting, which will prove to be useful for demand response programs designed to improve grid reliability. Comfort and amenity can also be improved. Similar activities have been conducted or are underway in research institutions across the world using either macroscopic devices such as louvers and shades (including double-envelope systems) or microscopic coatings on glass (i.e., electrochromic, gasochromic, thermochromic glazings) [Compagno 1999, Lee et al. 2002].

These studies show that the technical energy-efficiency potential for smart integrated window-daylighting systems is promising and can yield significant reductions in US commercial building energy use if adopted by a significant percentage of the market. However, conventional automated shades and daylighting controls have been commercially available for over two decades with less than 1-2% market penetration in the US. So we must ask ourselves what is the market-achievable energy savings for these technologies? Daylighting technologies face significant first-cost and non-economic barriers, unlike prior drop-in replacement technologies such as the successful low-E windows and electronic ballasts of the 1980s, which now enjoy 40-50% market share. Energy costs represent approximately 1% of the total commercial building annual operating expense and these costs are typically passed through to the tenant. Building owners invest in measures that yield the highest rates of return. With a payback of 10+ years given the initial cost of these emerging technologies (with mature and lower cost products, payback time decreases), these technologies are unlikely to be adopted based on savings on energy costs alone. The added value, non-energy benefits can be used by early adopters/ building owners to justify such investments. We would argue that these added-value benefits are now becoming more relevant in a competitive real estate market due to the movement toward and market recognition of sustainable building design. Not only are reductions in energy use, peak demand, and reduced HVAC capacity relevant, improved environmental quality, comfort, and health are increasingly capturing the attention of building owners and facility managers.

In today's market, daylighting appears to be enjoying a comeback. After the 1980's architectural trends towards using "dark" tinted or reflective glazing to control solar heat gains and the availability of competitively priced, clearer, more transparent spectrally selective low-E windows, architects are now enjoying the freedom of being able to specify large-area clear windows without the penalties of solar heat gains. The design aesthetic of the EU landmark status double-envelope buildings constructed in the 1990s has migrated to the US. These façade designs are more open and communicative to the urban environment and are purported to counter some of the maladies of the 1980s and 1990s – sick building syndrome, seasonal affective disorder, etc. – by providing plentiful daylight, view connection to the outdoors, and natural ventilation. Technological advances in computer monitors also enable the interior daylight levels to be raised without reduction in task visibility. Digital control systems are more robust enabling more reliable real-time optimization of environmental controls.

As with all innovations, the problem with accelerating market adoption is of decreasing risk. Most building owners and A/E teams are risk averse and don't want to be the first to adopt a new technology. As the building owner researches technology options, the usual questions surface that concern the purchase of any new product: how will it work for my application, are the vendor claims valid, what risks are incurred, and will the performance benefits be sustained over the life of the installation? Most designers and owners do not have ready access to answers to these questions, thus slowing the adoption rate of innovative technologies. In the case of daylighting controls, the technology has been on the market but due to historical failures and high cost, lighting designers avoid suggesting such systems to their clients. With commercially-available automated shading systems, the same can be said: the few anecdotal case studies available in the US have indicated that there was occupant dissatisfaction and rejection of the system. In general, there is considerable uncertainty over the performance of innovative systems. Inadequate simulation tools lead to incorrect conclusions on the overall benefits of such systems. The design team must determine if such systems increase cooling, visual discomfort, occupant dissatisfaction, or have other unknown impacts. High first costs and commissioning costs are major deterrents.

Monitored field tests on emerging technologies help to provide such information to end users thus reducing risk. Other mechanisms can be used jointly with field tests to reduce cost. In support and in parallel with the US Department of Energy's (DOE) activity toward developing innovative technologies, other US public agencies that advocate energy efficiency also promote technological innovation in building science for the purposes of reducing global climate change, achieving independence from foreign oil sources, improving grid reliability, and postponing the expansion of conventional generation capabilities. The "loading order" for California, New York, and the Pacific Northwest is energy efficiency as the first priority, renewable energy, then conventional generation as a means to meet the growing demand for energy use in the years to come [Peevy 2004]. Many of the "emerging" technologies programs supported by these public agencies are not focused on developing the basic innovative technology like DOE, rather bridging the gap between innovation and commercialization. The main objective of these programs is to transform the market for emerging technologies so that energy-efficient products become the norm. Interventions used to get technologies to market include R&D support (using a venture capitalist model for funding innovators), putting a competitive market in place, documenting and demonstrating that the technology works and generates energy savings in real world applications, providing field demonstration support so that third party performance data are made available, and providing technology subsidies, consumer education, technology training, technological assistance, etc. in support of deployment. Among these programs, the New York State Energy and Research and Development Authority (NYSERDA) promotes technological innovation through their R&D product development program which selects project teams using competitive solicitations with a 50% cost-share requirement to share the risk of innovation. The types of technologies they promote are ones that do not require being pushed into the marketplace, rather those that are being demanded in the marketplace. Their most successful value propositions have been those that provide energy savings as well as other benefits [Douglas 2004].

Having seen LBNL's research on dynamic shading and lighting systems, The New York Times approached LBNL for advice. Their new corporate headquarters was designed to promote "transparency" to the public (being a news organization that provided factual information to its customers) via floor-to-ceiling clear glass windows shaded by a unique exterior shading system. Enhancing the way employees work was the key objective, with sustainable building design as a second objective. The Times learned on their own devices that some sustainable designs would help them achieve their primary goal since they believed that such designs foster employee (occupant) creativity, productivity, health through the environment of the space and its connectivity to the outdoors.

Sustainable building design was a key objective. To control window glare and promote daylight harvesting, automated roller shades and daylighting controls were under consideration. The slow rate of market adoption has been due primarily to cost barriers but other issues such as system reliability have also impeded their use. The New York Times was willing to consider these technologies but needed third party data to understand the risks associated with the use of such technologies.

The partnership that was subsequently created between the building owner, LBNL, and industry met the requirements of the NYSERDA R&D product development program. The integrated technologies held significant potential for energy-efficiency while adding other amenities of value to commercial building owners. Additional cost-share was provided by DOE and by the California Energy Commission Public Interest Energy Research program. The overall strategy the building owner employed was a good one. To achieve a competitive marketplace, the building owner built a full-scale daylighting mockup and invited two sets of vendors to install their shading and daylighting equipment. This field test formed a key strategic cornerstone for accelerating an industry response to the building owners' challenge to a sleepy market (i.e., US automated shading and daylighting control products have had few major technical advances over the past 10 years). At LightFair 2004, the major US lighting convention, The New York Times issued a challenge to industry in the form of a "big, hairy, audacious goal (BHAG)" (made popular by the Harvard Business Journal [Collins et al. 1994]): 1) there should be no premium for a dimmable system in a commercial office building, 2) lighting control systems need to self-commission, and 3) whoever can do this will own the market. At the same time, the building owner publicized the project gamering interest from many architectural and engineering publications and gave tours of the daylighitng mockup to interested parties, including major building owners and developers in the Manhattan area. At the end of the field test, the building owner incorporated what they learned about each system and created a procurement specification. This procurement specification was let out to eligible manufacturers for competitive bidding. The winning vendors were then invited in a further partnership with the building owner and LBNL to develop, test, and prove the capabilities of their systems in the daylighting mockup prior to installation in the final headquarters building.

This report documents this major R&D effort to accelerate market deployment of automated shading and daylighting control technologies (future activities will be added as an addendum to this report):

**Early Design**

- **Section 2:** For the purpose of project documentation, the building owner's early rationale and requirements for these technologies are stated prior to working with the actual technologies in the daylighting mockup.
- **Section 3:** Several alternative shade designs and control strategies were explored using the Radiance visualization tool to determine if interior daylight illuminance could be increased over the base case design.

**Field Test at the Daylighting Mockup**

- **Sections 4-6:** These sections present lighting energy use, control system performance, and visual comfort data that resulted from field monitoring at a full-scale daylighting mockup under real sun and sky conditions over a nine-month period. A whole buildings approach to energy-efficiency is needed to address the dynamic interactions between the building and the environment, among the building's various energy systems, and between the building and the occupant. The discussion focuses on how the dynamic systems were tuned to achieve a good balance between the competing requirements.
- **Section 7:** This section presents the results from a subjective survey conducted on 53 subjects who spent approximately four hours in the daylighting mockup performing their normal work activities in the provided workstations.

**Bid and Procurement**

- **Section 8:** This section provides the final procurement specifications that were used for bid and award of the largest procurement of automated roller shades and daylighting controls in U.S. history.
- **Section 9:** Pre-shop drawing engineering studies were conducted using the Radiance visualization tool. Data and images were provided to help the lighting controls manufacturer specify zoning and photosensor placement for the daylighting control system. Annualized data were provided to the roller shade manufacturer and building owner to assist them with their decision on the proper types of roller shade fabrics to be used on the various orientations and floors of the final headquarters building.

**Outreach Activities**

- **Section 10:** Provides information on the types of market transfer activities that occurred to accelerate market adoption of cost-effective daylighting systems.