100 Years of Innovation with Light

The Web Adventure

Holst Memorial Symposium
and Lecture **2014**

TU/e Technische Universiteit **Eindhoven** University of Technology

PHILIPS

100 Years of Innovation with Light

The Web Adventure

Holst Memorial Symposium and Lecture **2014**
Philips & TU/e

Contact:

Published by the Holst Committee,
Eindhoven, the Netherlands,
March 2015

Contact Information:
Conference Office TU/e
P.O.B. 513
5600 MB Eindhoven
The Netherlands

https://www.tue.nl/universiteit/over-de-universiteit/academische-plechtigheden/holst-memorial-lecture/
conferences@tue.nl
T +31 40 247 4000

A catalogue record is available from the Eindhoven University of Technology Library

ISBN: 978-90-386-3825-6

Foreword

The 2014 Holst Memorial Lecture and Symposium were organized by Philips Research and the Technische Universiteit Eindhoven (TU/e). On Thursday 13 November, the Holst Lecture, the 38th since 1977, was given by Dr.ir. Robert Cailliau, co-inventor of the World Wide Web, the internet based hypermedia initiative for global information sharing. The Internet is now experiencing a second phase towards the Internet of Things, which will have a significant influence, also on the Future of Lighting.

Honorary Holst Medal

On the occasion of the Holst Memorial Lecture 2014, the year in which Philips Research celebrated its Centenary, Dr.ir. Eduard Pannenborg received an Honorary Holst Medal for his important contributions to the Research and Innovation Policy at Philips.

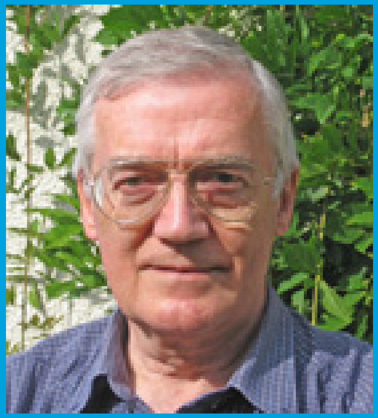
Symposium 100 Years of Innovation with Light

The theme chosen for the 2014 Holst Symposium reflected both the history and the future of Lighting Research. Eminent speakers from both the Academic and Lighting Innovation Communities addressed scientific and other developments impacting lighting and the effect on people. This publication captures the essence of the event.

Content

01

The Web Adventure

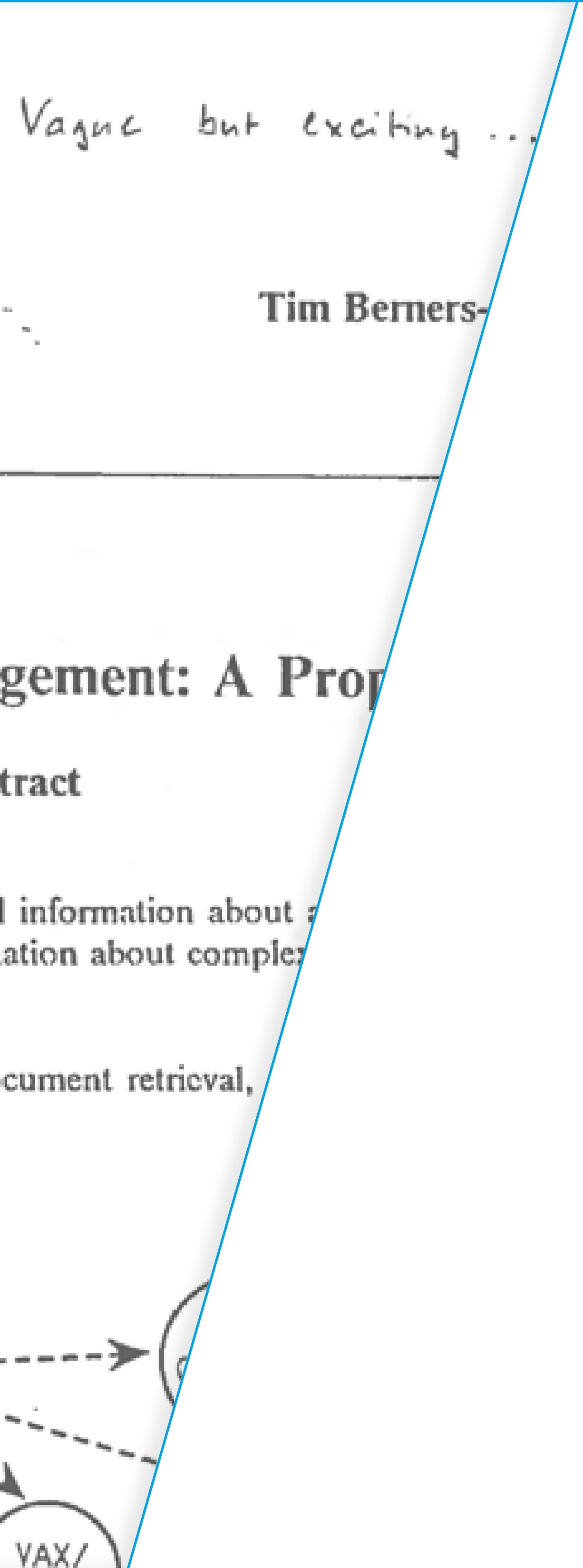


Dr.ir. Robert Cailliau
Former Staff Member
CERN, the European
Laboratory for Particle
PhysicsHolst Medal
Recipient 2014

Born 1947 in Tongeren, Belgium, Web Pioneer Robert Cailliau studied at Ghent University, where he received an MSc (Electrical and Mechanical Engineering) and at the University of Michigan (MSc Computer, Information and Control Engineering). From 1974 to 2007 he worked at CERN, the European Laboratory for Particle Physics in Switzerland. Around 1990, Cailliau and his colleague Tim Berners-Lee proposed a hypertext system for access to the CERN documentation, which eventually led to the World Wide Web, a name coined in that period.
Cailliau started the International WWW Conferences in 1993, and is co-founder of IW3C2 (the International WWW Conference Committee). In 1993 he was instrumental in making CERN put the web into the public domain. In 1994 he started the European Commission's Web for Schools project. His publications range from topics related to mechanical engineering and computing to a History of the World Wide Web. He received various awards, which include the 1995 ACM Software System Award (with Berners-Lee) the 1999 Plantin Prize (Antwerp) and the Medaille de Genève Reconnaissante. He also received three honorary doctorates (University of Ghent, Southern Cross University, Université de Liège).

The messy reality of the innovation process is often obscured by the media push to accredit an invention to a specific individual, overlooking the important contributions of earlier workers in the field. Take the Wright brothers for example: while their development of a control system for airplanes enabled them to carry out the first powered flight, their success was dependent on a large body of ground-breaking work by other aviation pioneers, many of whose discoveries had been incorporated.

The development of the World Wide Web (WWW) provides a more recent example of this phenomenon. Like many success stories, it began with a bright idea, and its invention is attributed to a deserving individual, Tim Berners-Lee. But this condensed version of the history of the Web belies its long and complicated gestation, the myriad twists and turns in the tale, and the many players that contributed to its development.



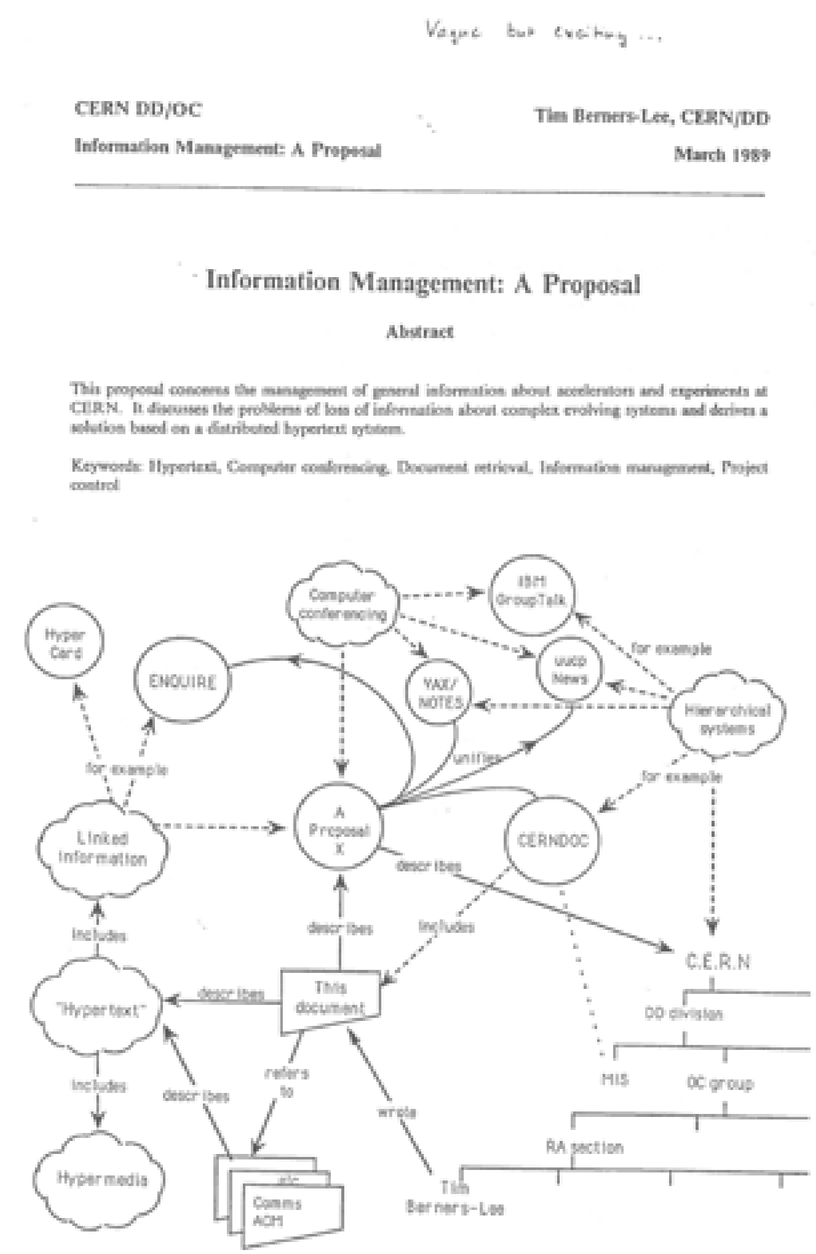
The prelude

The innovation that ultimately gave birth to the Web drew on several pre-existing concepts and technologies, specifically Ted Nelson's work on hypertext, Doug Engelbart's pioneering studies of human-computer interactions, and the packet-switching network of Louis Pouzin. The vision of the Web can be traced back even further to Paul Otlet, a Belgian thinker and pioneer of information science who sought to catalogue the world's information in a Universal Bibliographic Repertory, which held 16 million index cards by 1934. He also presaged several features of the current Web by envisioning a system that would make library texts available to the reader for remote viewing using telephone and television.

The creation of the World Wide Web

The Web was created in response to a need for better communication of information at CERN, the European Laboratory for Particle Physics, specifically the documentation that would be produced for the yet-to-be-built Large Hadron Collider (LHC). An effective system was needed to facilitate the automatic sharing of this information between scientists and institutions across the globe. Although the Web predates the LHC by two decades, it should be considered its first "spin off".

The inception of the Web can be traced back to two separate proposals drafted in 1989 by Tim Berners-Lee and Robert Cailliau, both of whom worked at CERN but were unaware of each other's research. Berners-Lee's proposal for information management had been deemed "vague, but exciting" by his manager Mike Sendal, and received a less than warm response from hypertext pioneer Ted Nelson, who ➤


Vague but exciting ...

CERN DD/OC — Tim Berners-Lee, CERN/DD

Information Management: A Proposal — March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext system.

Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control envisioned a superior, yet ultimately unimplemented system. However, the proposal was passed on to Cailliau, who immediately saw its merits and redrafted it in a way CERN management could better understand, and the project got a green light. Cailliau's communication skills proved an important asset when explaining exactly what the Web was, and how it would work, to fellow scientists, policy-makers, and politicians. This experience ultimately led to him serving as the Head of External Communications at CERN, and taught him much about the importance, and the inherent difficulty, of communicating new ideas, particularly those which are continually developing and, in many cases, not fully understood by their creators themselves. This sense of the unknown was evident in the many animated discussions between Berners-Lee, Cailliau and others during the birth of the Web about the potential implications of such a powerful technology.

Birthing pains

Berners-Lee developed the first web server at CERN in 1990. While domain name systems and file system paths existed at this point, and SGML-type mark-up was well-known, Tim's brilliant contribution was to combine these concepts to create the Uniform Resource Locator (URL). Like the Wright brothers' control system, this was the missing piece of the puzzle – a naming scheme that could refer to any document, anywhere in the world, whether real, synthetic or even yet to be conceived. By the end of 1990, a working web, featuring the world's first web browser, the first server software, and the first web server, was up and running.

The original browser allowed users not only to view web documents, but also to create and edit them. There was thus no distinction between browser and editor; producing a web page was as easy as reading one. This first browser perhaps best epitomizes the original ideal of the web, described by Berners-Lee as „a collaborative medium, a place where we [could] all meet and read and write".

However, the original software ran only on the NeXT computer workstation. While the NeXTStep software development system was well ahead of its time, only about 50,000 NeXT workstations were ever produced. This prompted to the development of a more adaptable system, the Line Mode Browser. This much simpler text browser could be run on most computers of that time, providing greater portability, but at the cost of greatly reduced functionality: no editing functions, no graphics. The user experience was restricted to passive viewing of content, a limitation Cailliau describes as catastrophic because the Line Mode Browser was used as a basis by competitors seeking to develop a better browser, resulting in minor improvements on what was essentially a much inferior design when compared to the original browser. ➤

By 1993, the WWW accounted for 1% of internet traffic, managed via 250 servers located in academic institutes throughout the world. That same year Cailliau managed to convince CERN to put the WWW into the public domain, thus making it royalty-free, non-proprietary, and available to the public. The following year saw the creation of the World Wide Web Consortium (W3C), founded by Berners-Lee, and supported by the European Commission, the Massachussetts Institute of Technology (MIT) and the Institut National pour la Recherche en Informatique et Automatique (INRIA). W3C was tasked with overseeing the development of open web technology standards and recommendations to improve the Web, and continues to play a crucial role in the evolution of the Web as we know it today.

The subsequent exponential growth of the nascent Web can be largely attributed to its scalability. While other hypertext system such as Microcosm and Hyper-G offered much greater functionality, their scalability as networked systems was markedly inferior to that of the Web. The downside of this scalability is that the Web still offers users no easy way to publish online. This need ultimately spawned the Web 2.0 explosion, which for the first time provided the broader public the ability to generate and share their own content.

Web 2.0 and future challenges

The exploitation of this niche led to the rapid growth of social media and web application industries, epitomized by Facebook. These developments heralded a new era of user collaboration and brought to light a raft of new challenges that would face the Web in the coming years. Chief among these were the commodification of user access to information and the challenge of restricting excessive commercial greed. By this point, Google had assumed the role of the de facto gatekeeper of the web. This was achieved by using massive parallel computing to overcome an inherent difficulty of interlinked web documents: developing efficient search engines. With the rise of Google and Facebook came major concerns about the potential influence of monopolies on the developing Web. Increasing Web access also raised important questions about the Web's influence on society: at what point do the disadvantages of the interconnectedness offered by the Web begin to outweigh the benefits? This interconnectedness has now extended beyond the virtual Web with the advent of the Internet of Things (IoT) – the growing availability of devices that can be embedded within the existing structure of the internet. While these developments undoubtedly hold great potential, the negative effects cannot be ignored. Before attaching too much importance to the IoT Cailliau believes ➤

things themselves should be examined first: he sees modern design as a repeat offender in championing the form of devices over their function, jettisoning useful functionalities for the sake of some minimalistic ideal. The burgeoning IoT also highlights the need for careful deliberation about risks to privacy and ownership, the very concepts of which are at risk of becoming blurred: to what extent does one “own” a device when its software is essentially rented, updates are continually required, and access is offered only via "neo-feudal", central sites?

A visiting journalist at CERN once noted with astonishment that the institute was staffed by people who were willing to change their outlook in the face of evidence. While taken as the fundamental tenet of scientific research, this mind-set does not apply to all spheres of endeavour, yet is crucial for the survival of humanity. Given the enormous and ever-growing impact of the Web on every aspect of human life, it is essential that future innovation and the implications thereof be carefully considered to ensure that the overall benefits of the Web to society outweigh its potential cost. ■

02

Lighting Research: a Historical Perspective

Prof.dr. Cees Ronda
Philips Research, Eindhoven, the Netherlands and Zhejiang University, China

Cees Ronda studied Inorganic and Theoretical Chemistry in Groningen, the Netherlands. He joined Philips Research in 1986 and has been located in Eindhoven, Aachen (Germany) and Shanghai (China). Cees has worked on luminescent materials for light sources, displays and medical applications. He also studied thermionic emission in relation to Hg-consumption mechanisms and radiation transport, both in fluorescent lamps. His current interests are in light generation beyond lighting applications and air purification. Cees Ronda is chairman of the Brainbridge: an international research cooperation between Philips Research, TU/e and Zhejiang University (China). Ronda was awarded the Pannenborg Award in 2005.

In the 200,000 years since humans first used the sun as a lighting source, lighting technology has undergone many dramatic developments, which in turn have been closely linked to major advances in many other areas of human endeavour. The many Nobel prizes awarded for with lighting-related milestones underscore the importance of light sources as drivers of discovery. Max Planck´s discovery of energy quanta, for which he received a Nobel prize in 1918, provided the first explanation of the working of the incandescent lamp. Similarly, Max Bohr´s description of atomic structure played a crucial role in explaining the workings of gas-based and fluorescent lamps, while Owen Williams Richardson pioneering work on thermionic emission described the basic principle of fluorescent lamp operation – the conduction of electrodes through an inter-electrode plasma. This year, the fundamental transformation of lighting technology heralded by the light-emitting diode (LED) was recognized with the awarding of the Nobel prize to the inventors of the blue LED.

Increased control

Each stage in the evolution of light sources has seen an incremental increase in the control afforded to the user. Open fire and oil lamps offered little control: the intensity of the light was determined by the quantity of fuel that could be burned in a certain volume. However, the development of gas lighting in the early 19th century allowed widespread indoor and outdoor illumination of the cities of the time. The subsequent development Edison´s incandescent electric lamp in the early 20th century, often described as the greatest invention since man-made fire, was a milestone in both lighting technology and quantum physics. Edison's invention for the first time allowed affordable lighting for widespread residential use. The subsequent search for a more efficient light source led to the commercialization of the fluorescent lamp in 1936. Fluorescent lamps emit light via a cascade through which UV light is transformed to visible light by luminescent materials. Compared with older light sources, fluorescent lamps also offered better colour rendering, a measure of how well a source reproduces all natural colours.

Research at Philips into the technologies underpinning incandescent and fluorescent lighting led to several important findings. For example, findings in the fields of vacuum technology and metallurgy played important roles in the development of later Philips products, including the x-ray tube and the picture tube, which kick-started Philips Healthcare and Philips Consumer Lifestyle divisions, respectively. Similarly, work by Philips on fluorescent lamp technology led to important advances in inorganic material science and the physical characterization of materials, and furthered our understanding of the requirements for good colour rendering, and the materials needed to achieve this.

LEDs: the future of lighting

The development of inorganic LEDs in the late 20th century for the first time saw material control on the nanometre scale, in addition to greater colour rendering and unprecedented energy efficiency. These LEDs rely on quantum dots, also known as artificial atoms, which can selectively hold or release electrons, and depending on their size can be modulated to emit any colour desired, thus enabling tunable light emission. This allows the production of monochromatic light at almost all wavelengths, and modulation of the light emitted (and power consumed) over a massive range, a feature not offered by any other light source.

New business model

The development of LEDs has had a marked impact on the manner in which the lighting industry operates, heralding a completely new business model, which is more akin to that of the semiconductor industry. For example, where in the past lighting companies produced their own machinery in sites located close to production plants, this technology is now sourced exclusively from specialized third party providers. LED production also necessitates a much larger piece number per factory as compared with incandescent and fluorescent light sources. An additional challenge of LED production is the market saturation of key applications such as mobile handset and TV backlighting, which leads to high price erosion. This creates a powerful incentive for companies to increase the number of applications in which LEDs can be used, and to reduce manufacturing costs, which in turn has driven innovation in manufacturing processes. One such example is the growth of gallium nitride on silicon wafers: while more complicated than currently-used techniques, this approach allows the production of much larger wafers, on which LEDs are produced, at lower cost driven by the roadmap of the Si-industry.

New applications

Over 200 years of scientific research has pushed light source performance to physical limits, resulting in the development of LED-based lamps with very high energy efficiency (over 70%) and high luminous efficacy. Thus, to remain competitive, companies must explore new avenues through which light sources can be further optimized.

Thankfully, cutting edge lighting technologies bring with them a host of potential applications that were previously impossible with traditional lighting sources. One of the best known applications is backlighting in personal devices such as mobile phones and flat screen TVs. In these devices, LEDs allow extreme miniaturization and provide saturated colours at very high contrast. LEDs can also be incorporated into smart light management systems for cities, allowing greater control and reducing costs. The unique properties of LEDs have also been exploited in industries as diverse as horticulture and healthcare. Because the light and heat produced by LEDs can be coupled out in different directions, LEDs are an ideal light source for crops, causing none of the drying effects experienced when using incandescent grow or discharge lamps. Moreover, the colour tunability of LEDs allows the selection of the optimum “lighting recipe” for a given plant type, ensuring a maximum yield. This property also allows the selection of optimum light setting in schools and hospitals. The patient benefits of intelligent networked LED systems in hospitals (Philips Healwell system) include increased sleep duration and faster recovery rates. Philips Schoolvision, a similar concept applied to classrooms, allows the teacher to select the most appropriate light settings for a given activity. Other health applications of LEDs include the use of compact UV light to kill pathogens in drinking water, and the use of high-intensity narrow spectrum light emitted by LEDs for bacterial disinfection in hospital settings.

03

Lighting Systems that Think

Towards Autonomous Lighting Optimization and Control

Dr. Robert F. Karlicek Jr., Professor of Electrical, Computer and Systems Engineering. Director Smart Lighting Engineering Research Centre at Rensselaer Polytechnic Institute, Troy, NY, USA

Dr. Robert F. Karlicek, Jr. is the Director of the Smart Lighting Engineering Research Center at Rensselaer Polytechnic Institute (Troy, NY, USA), a NSF and industry funded program exploring advanced applications for next generation solid state lighting systems. Prior to joining RPI, he spent over 30 years in industrial research and R&D management positions with corporations including AT&T Bell Labs, EMCORE, General Electric, Gore Photonics, Microsemi, Luminus Devices and SolidUV. His technical experience includes epitaxial growth of high performance LEDs and lasers, advanced device fabrication and high power LED packaging, thermal management, control systems design and applications in solid state lighting as well as other novel LED uses such as IR and UV LED applications. He obtained his Ph.D. in Physical Chemistry from the University of Pittsburgh and has over 40 published technical papers and 38 U.S. patents.

Smart lighting, or in other words, lighting that thinks, is an important trend in the future of lighting. There may still be technologies beyond LEDification – LASER lighting may prove to be still more efficacious in terms of sheer luminance – but the technology of both producing and controlling light are well defined. It is the computing revolution, embodied in the “Internet of Things”, which offers the next perspective in lighting that can better deliver on its full potential. The key challenge is sensing and understanding the environment to be lit, and the needs of its occupants.

Unlocking the potential of Solid State Lighting

In comparison to traditional lighting technologies, LEDs have many advantages. As the availability of lower cost LEDs meets the growing demands for energy efficiency, this is already leading to the global replacement of conventional light bulbs with LED lights, also referred to as the “first wave” of solid-state lighting.

However, just replacing incandescent and fluorescent bulbs with LED bulbs leaves a large potential of LEDs untapped. The full power of Solid State Lighting (SSL) lies in its ability to combine light-emitting functions with information transmission. Every node or energy point from which light emanates can now work with data collection nodes to enable unprecedented sensing, and thus controllability. SSL provides the means to completely transform and digitize lighting, thus enabling what could be called the “second wave” of solid-state lighting, or smart lighting, that use the data in the lighting environment to autonomously adjust for greater comfort, productivity, safety and efficiency.

The future of the lighting industry

The reliability of solid-state lighting systems will challenge the century-old business models supporting conventional lighting markets and businesses. SSL lifetimes exceeding 60,000 hours, and thus essentially eliminate the need for sockets in new lighting installations (when there is no need to change the bulb, why would you need a socket?). To stay in business, incumbent lighting companies must develop new business models that go beyond just selling lamps and fixtures.

In compensation, the wide range of SSL characteristics and benefits open up new business opportunities, ranging from integrating light into furnishings and building structures, to intelligent lighting systems and solutions, to providing lighting as a service. These exciting new business opportunities are also attracting players from outside the traditional lighting industry. In particular Internet companies such as Google, Apple, Cisco and Huawei are entering the lighting market, eager to use the potential that the embedded sensors and data collection offer, to provide new intelligent features and services.

As hinted at by the involvement of Internet companies. the lighting landscape will be affected by the ubiquitous connectivity inherent in the Internet of Things (IoT). Microprocessors will be a key ingredient in any future lighting system, as the basis for comprehensive data processing that enables lighting systems not just to be more efficient, but also to provide new features and services. Lighting as we know it will disappear. It will be replaced by smart lighting that completely transforms the way we interact with lighting.

Smart lighting – more than illumination

Smart lighting systems can be described as lighting systems that can think and act, and therefore are able to provide optimized lighting wherever and whenever it is needed. Instead of human control, smart lighting uses complex sensor networks, advanced control methods and elaborate computational technologies to respond quickly, autonomously and intelligently to changes in the lit environment. Similar to the virtual, "expert" driver whose knowledge is embedded in a self-driving car, the expertise of a virtual lighting designer is contained in a smart lighting system. Potential applications for smart lighting span the entire spectrum from illumination and entertainment, to health and information. Some examples would be:

- Adaptive Lighting Systems
- Visible Light Communication
- Illumination Video Fusion
- Biosensing
- Circadian Rhythm Management

Adaptive Lighting Systems

Adaptive Lighting Systems use real-time sensing technologies to uncover how light flows in a specific space, and sense and analyze how that light is being used. This lets them optimize the specific lighting environment. Such sensing technologies include light transport analysis and time-of-flight mapping.

Light transport analysis modulates color (without a perceptible flicker) into the lighting, to identify – in real-time and at a very low resolution – how a space is being used. Based on this information the lighting can be tailored to the specific activities in that space, delivering just the right amount of light in the right locations.

Technology for infrared time-of-flight (ToF) mapping is fairly common, and is used, for example, in speed traps. Visible light time-of-flight mapping is a new application for this type of data collection. Adaptive lighting systems can use distributed, flicker-free modulation of the light, and high-speed sensors, to measure distances and provide accurate information about objects or movements in a space. For example, to track people as they enter or move through a space, and even provide coarse recognition of poses – whether a person is lying, sitting, or standing. Resolution can, of course, be controlled to preserve privacy. This provides information to infer how people are using a space, to create a lighting environment that adapts and responds to specific use scenarios.

Initially, the user needs to provide feedback, to help the system "learn". The ultimate goal is autonomous lighting that continues to learn and adjust, to provide "always right lighting" without the human in the interface. Apart from the increase in comfort and safety, this has the potential to drastically enhance energy efficiency. And the information from the lighting system could have applications beyond illumination, for example in home monitoring for elderly or infirm people living alone.

Visible Light Communication

Visible Light Communication (VLC) refers to communication capabilities that can be embedded in digital lighting systems. These use flicker-free, high-frequency modulation of the visible light between 375 and 780 nm for data transmission. With the ever higher demand for data, radio frequency wireless communication traffic is facing increasing crowding. ➤

VLC provides an alternative means of data transmission, that can provide higher data rates, increased bandwidth, and – through the ability to localize data delivery – better privacy and safety. This makes VLC more and more attractive.
An important prospective application for VLC is indoor GPS. Such a system uses specifically-modulated light to encode location information for mobile devices within buildings. A camera on the mobile device can pick up the signal and the device can then recognize its position. This could be to improve access to navigation services, for example, inside buildings such as hospitals, office blocks, shopping malls, or airports; or for complementary information services at trade shows, or in galleries or museums.

Illumination Video Fusion

Another interesting application of smart lighting systems is the combination of illumination with video information. This makes it possible for the lighting system to offer functions like virtual skylights and windows. This can be to display video images from the immediate environment, or to modulate light corresponding to external lighting conditions. Such applications are interesting for locations where natural light windows are not possible (such as in patient rooms in the basements of hospitals, or in the interiors of large offices or public buildings). Such ambient lighting solutions can transform enclosed interiors into more restorative environments, and contribute to people's sense of well-being.

Biosensing

Biosensing technologies use high performance LEDs to detect contamination, for example in healthcare applications. This technology exploits the fact that ultraviolet LEDs at 280 to 330 nm induce fluorescence in biological systems such as viruses and bacteria, thus making them visible to the naked eye. Interestingly, visible light at 405 nm can kill certain bacteria, by disrupting electron transfers in the cell. So light can also be used to decontaminate.

Circadian Rhythm Management

Studies of the human circadian rhythm show that the daily variation in the blue spectrum of visible light contributes to the synchronization of the cortisol and melatonin cycles that impact our sleep. Disrupting this variation can affect sleep quality. This means smart lighting systems could be equipped with color-tunable lights that can mimic the changes in natural light to encourage a healthy circadian rhythm.

Since the circadian rhythm directly affects human health, well-being and productivity, this is an area that receives a lot of attention from research institutes as well as healthcare institutions and enterprises. The latest research at the Rensselaer Polytechnic Institute, has successfully developed a sensor technology that can detect an individual's circadian phase in around eight hours – a process that has traditionally taken three to four days to complete. This shortens the control loop dramatically, and opens the door to further research in wearable sensors that could be used to optimize lighting to control circadian rhythms for a wide variety of applications.

In this, as in the other cases mentioned here, and still others in research and development, smart lighting expands the possibilities of lighting far beyond illumination. Smart lighting has the potential to touch and improve many aspects of our lives, and create a fundamental shift in the way we interact with lighting.

04 Measuring the Subjective Response to Lighting

Prof. Steve Fotios
School of Architecture, The University of Sheffield, United Kingdom

Steve Fotios is professor of Lighting and Visual Perception in the Sheffield School of Architecture (UK) where he leads research of lighting and human factors for interior and exterior environments. Two elements of this activity are the influence of lamp spectrum on spatial brightness for interior lighting, and empirical evidence of the benefit of lighting for pedestrians. A key theme of his research is experimental design, establishing and checking procedures so that there is a better understanding of what is being measured, and this work formed the basis of a recent CIE publication, CIE 212:2014, which presents guidance towards best practice in psychophysical procedures used when measuring relative spatial brightness. One of his proudest achievements was to set up LumeNet, the research methods workshop for PhD students of lighting, giving new researchers a chance to meet and learn from experienced researchers at an early stage in their career.

Spatial brightness describes the subjective, visual sensation associated with the magnitude of ambient lighting within an environment, such as a room or lighted street. While alterations in the spectrum of a light source can be quantitatively determined, light perception is highly subjective. Because a host of potential biases can influence the end result, the measurement of this parameter presents a unique set of challenges.

Bias and the measurement of visual perception

There are myriad opportunities for bias in studies of visual perception: Poulton was correct that “quantitative subjective assessments are almost always biased, sometimes completely misleading”. For example, when subjects are given a light level controller and asked to select their preferred brightness setting, the mean result of a sample of test participants will be a setting that lies around the middle of the available range; different ranges will give different results, a phenomenon known as range bias. This was demonstrated in a study in which the author concluded a preference for 1750 lux as the ideal brightness for a work environment; this value represented the mid-point of the range over which the participants could modulate the brightness, and was selected despite the fact that the typical illuminance of work environments is much lower (500 lux). When participants in another study were asked to select their preferred level of brightness in three separate trials, unaware that the range was altered in each trial, they selected a different value for each trial, in each case corresponding to the near-centre of the range.

Individuals showed strong correlations in their selections from one trial to the next: those that selected values above or below the mean did so consistently in all trials. This tendency indicates that the observed results often have little to do with the lighting selected, and are strongly influenced by the way in which participants interact with the controller. Similar findings have been reported in studies of other parameters, such as colour temperature. However, centering bias can be used to advantage to promote energy saving: provide a dimmer switch with a range of 0-500 lux, and those individuals setting anything lower than 500 lux will be demanding less energy (but without reducing their satisfaction with the light level).

Another form of bias affecting studies of light perception is conservative adjustment bias. This is caused by a common psychological tendency to adjust insufficiently in tasks that require the test subject to estimate the value of a reference set-up by varying a comparable test set-up. This can result in the variable stimulus being set to a lower level than might be objectively expected. This form of bias can particularly influence the results of studies using a side-by-side matching design, that is, in which participants are asked to adjust one lamp to match the brightness of another.

Side-by-side matching studies are also susceptible to position bias, a phenomenon that accounts for the preferences shown by many to buy objects that are lit from the left or bisect a horizontal line slightly to the left of the centre. In most side-by-side matching studies, the participant can adjust the intensity of only one of two lamps. This creates a source of potential bias, and makes it increasingly difficult to attribute the obtained results to the light spectrum alone.

The generation of high quality data thus requires that specific protocols are implemented to counterbalance for these potential sources of bias. In side-by-side matching studies, this would require multiple test conditions, such as determining the effect of the position of the adjusted lamp (to counterbalance position bias) and allowing dimming in either side (to counter conservative adjustment bias).

Category ratings

Category ratings are frequently used to evaluate visual perception, by asking people to rate brightness using a response scale. However, using this approach, the number of points in the response scale can in itself affect the end result. For example, 7-point scales, by providing a discrete mid-point (4), have been shown to augment the centring tendency of study participants. Problems also arise when there are more items to rate than available scoring options, as this forces the subject to ascribe an identical score to non-identical levels of brightness. The results are thus influenced by the rating system itself, and may not provide an accurate reflection of the subject´s perception of the parameter of interest.

A scale can force the respondent to over- or underestimate the magnitude of an effect, or in other cases, to identify a problem where one does not exist. An example of the latter scenario is the 9-point glare scale, which requires that the responder rates the glare of a light source, but in many studies does not offer the opportunity to say “there is no glare”.

Taken together, these examples provide evidence that data based on rating scales should be interpreted with caution.

The language used to question the responder can also influence their answer, resulting in a biased response. For example, several studies require that responders score both brightness and visual clarity. Given that many researchers differ in their definition of these terms, it is unsurprising that this may result in confusion among study participants. This is borne out by the results of numerous studies in which responders ascribed comparable ratings to each of these two parameters.

Towards better quality data

One of Prof. Fotios´ main goals in developing a metric for the effect of spectrum on spatial brightness is to ensure the production of better quality data. However, this is dependent on good study design, which incorporates protocols to counterbalance potential sources of bias, such as null conditioning and swapping left and right sides, as described above. While these concepts are well known and have long been applied in studies of visual psychology, their use in lighting research has lagged far behind, with only a minority of spatial brightness studies including such measures.

Worryingly, the vast majority of studies, which failed to adequately control for potential bias propose, are cited as strong evidence of an experimental effect, but in fact may be significantly influenced by experimental flaws.

Lighting, a Creative Perspective

Luc Lafortune
Lighting designer,
Cirque Du Soleil

Cirque du Soleil – recognized all over the world for high-quality, artistic entertainment. Its productions seek to evoke the imagination, invoke the senses and provoke the emotions of people around the world. This is accomplished in a variety of ways: acrobatics, projections, music, costumes – and lighting. The audience's favorite moment in the Kà show, for example, takes the form of shadow puppetry. Two performers and three perfectly positioned lights among 3,000 lighting fixtures. A seemingly simple setup, yet it creates a powerful emotional response. What makes this possible? Technology applied in a way that supports and complements the show's overarching artistic vision and intent.

Luc Lafortune is one of the world's leading lighting designers as well as one of the original creators of the world-renowned Cirque du Soleil. He has been associated with the company since its inception in 1984. In thirty years, Luc has achieved an international reputation as one of the most daring and inventive designers. He has created iconic, exhilarating and profoundly moving imagery for some of the world's most revered artists. He works widely in both conceptual and technical development, having collaborated with the likes of Franco Dragone, Robert Lepage and Mark Fisher. At Cirque du Soleil, his résumé includes the shows O, Le Cirque Réinventé, Fascination, Nouvelle Expérience, Saltimbanco, Mystère, Alegría, Quidam, La Nouba, Dralion, Zumanity and Kà. He was also co-director of photography for the video recording of the show Quidam. Many internationally acclaimed artists have also called upon his talents. He has worked with No Doubt, The Eagles, Gipsy Kings, and The Dixie Chicks. In 2002, he worked with Peter Gabriel, designing the lighting for his world tour, Growing Up. The excellence of his work has garnered him many awards. In 1992, his design for the show Saltimbanco earned him a Drama-Logue Theater Award. In 1994, he received the Lighting Dimensions International (LDI) Lighting Designer of the year Award. In 1997, his work on Martin Professionals The Atomic Lounge, for which Luc Lafortune was artistic director, won the LDI Award for Best Light Show. In 1998, he received an Entertainment Design Award for his lighting design for the show O, as well as a THEA (Themed Entertainment Association) Award, in 1999. And finally, in 2005, Luc Lafortune was honored with the USITT (United States Institute of Theater Technology) Distinguished Achievement Award in Lighting Design.
Luc Lafortune is also a sought-after speaker, having been invited to share his knowledge and thoughts with students and professionals alike, all over the world.

A lighting professional's skillset

Lighting for productions such as Cirque du Soleil encompasses a number of different skills. Some are technological, requiring engineering knowledge. Others are artistic, requiring an understanding of the performer's craft (juggling, for example, or tightrope walking) and psychology (the artist's ego in particular). Although the mindsets behind these approaches may feel at odds with one another, these technical and artistic skills can, and should, work in harmony to help lighting experts express a show's creative message. (Please see the "Kà facts and figures" boxed text for more information on the Cirque du Soleil production referenced throughout this article.)

The interplay of skills, artistic vision, and collaboration – as seen in Kà

A lighting professional's job begins with an exploration of the creative vision driving the production. In layman's terms, the creative vision asks, "What do we want to achieve?" Kà, for instance, is characterized by a dark, apocalyptical look and feel – some have compared the stage lighting's mood to Ridley Scott's Blade Runner. And as with all Cirque du Soleil productions, Kà blurs the line between "theater" and "stage" in acknowledging its circus-tent origins. ➤

Telling a story through lighting

With the creative vision spelled out, a lighting professional can work out the technology underpinning it, asking, "How do we want to achieve it?" How, for instance, can lighting fixtures be arranged and operated to create a presence for performers who are dressed in dark costumes on a dark stage? If the inspiration and set pieces take shape as the Buddhist temples found in Kyoto, how can color mixing and LED lighting work together to render the wooden beams in moonlight and daylight? Indeed, the vision can dictate any number of engineering decisions, such as tools, colors, technologies, textures, and qualities of light.

This vision is also entwined with the collaboration inherent in a production of Kà's scope. With development processes taking years and involving multiple teams, a single overarching creative vision provides much-needed direction from start to finish. A lighting expert will, of course, consult with the director and design team. These conversations spark additional insight. They also instill important habits - train the mind to be curious and regard inspiration as a state of mind, not a switch to be turned on and off. On a more tactical level, teamwork is fundamental to a lighting professional's interactions with performers. The artists' needs (perform safely and consistently) must be balanced with those of the spectators (to see the performers). Lighting professionals must understand these challenges and constructively find solutions, such as positioning and backlighting, by establishing rapport and trust with performers. ➤

The right lighting allows the audience to see the performer – and it won't blind the juggler.

From words to images, from images to implementation

Where to turn for inspiration? A show's script acts as a natural starting point. Featuring many Shakespearean elements, Kà's script was broken down scene by scene. Each scene was then summarized into reactive words –such as "limpid," "dense," and "incarceration" – as a way of answering "What do I feel when I read this?". These words were researched, matched to associated images, and ultimately re-organized to match the flow of the story.

By first focusing on the artistic task of determining which scenes should evoke what feeling, Lafortune was in a better position to make intelligent technological choices for light fixtures, rhythm, the quality of light, and other goals. The book of collected images also helped various teams agree on and refer back to a single artistic vision throughout the two-year development process.

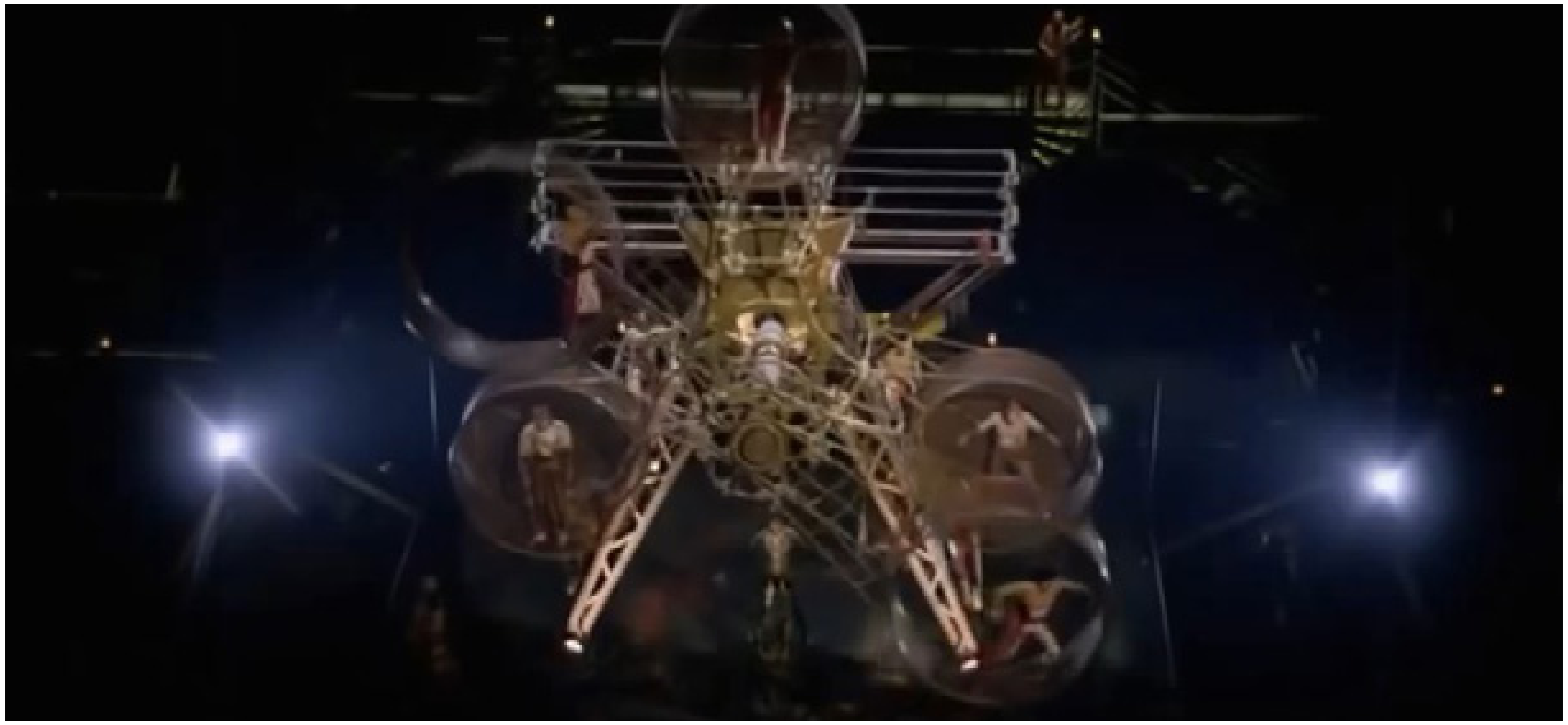
What "incarceration" looks like live.

Inspiration is all around us

"Be creative!" For many people, this command can be intimidating – not liberating. Where does inspiration come from? Having a clear, defined artistic vision helps immensely. By providing an abstract framework of what needs to be achieved, it trains the mind to be open to serendipity. Inspiration is in fact everywhere.

Kà's original set incorporated existing and found items already in the theater, such as air-conditioning conduits, an on-site beam projector, and a lighting bridge. The conduits required some dressing, but their basic structure was an excellent match to the collected images described above. The lighting bridge was also re-purposed to help performers move.

Inspiration can also be gleaned from specific sources. For a particular scene, the lighting team wanted to recall what a Roman audience might have felt watching gladiators in the arena. The aim was to trigger an emotional response rather than a rational one. The team decided to create the "feel" of a spectator sport by relying on stadium lighting (including floodlights).

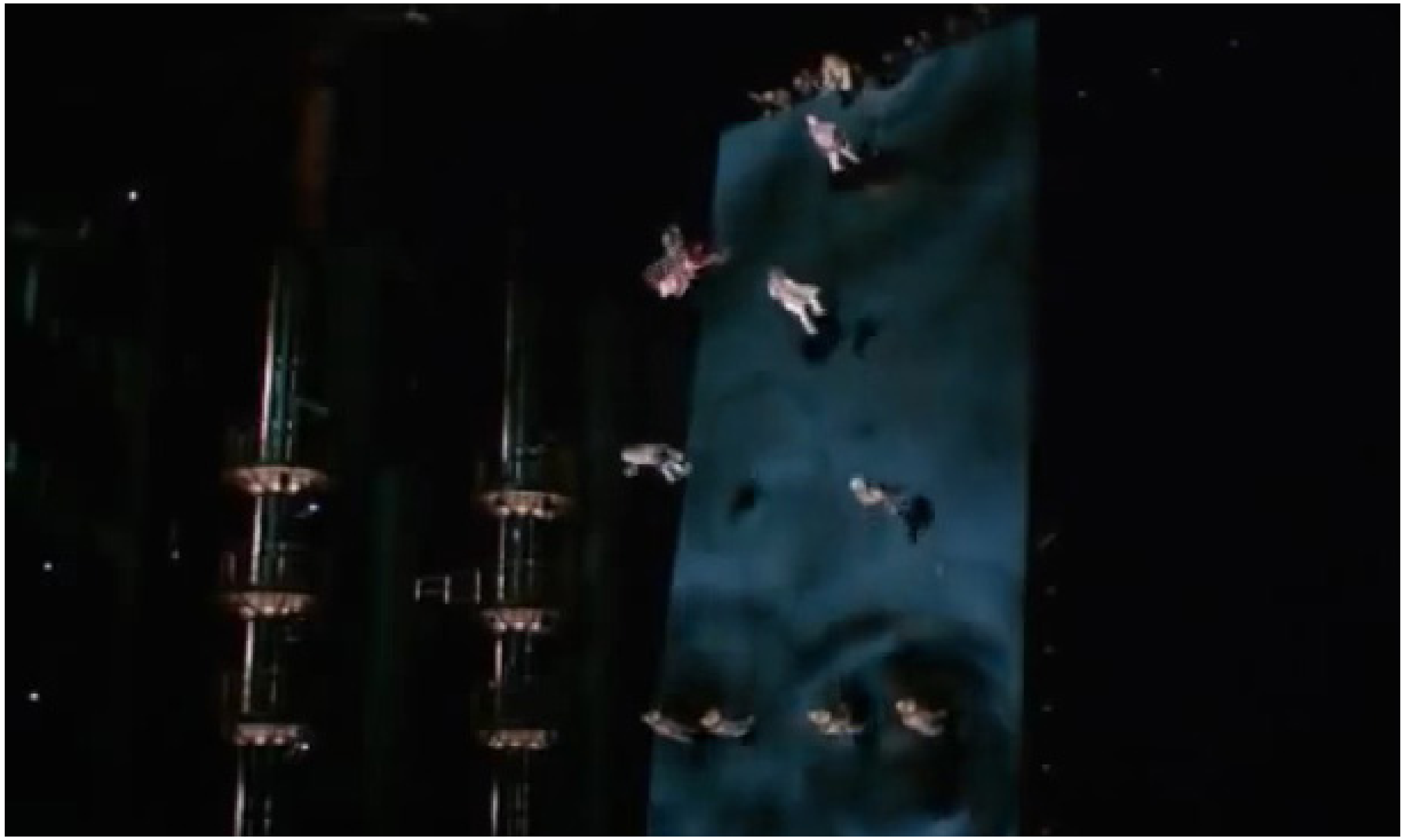


Note the lighting bridge behind the moving wheels.

Reversing the process: a cautionary tale

What happens when design follows technology? Teams set themselves up for failure. The production will lack composition and any underlying essence. Technical crews will know what they are doing, but not why they're doing it. This can lead to poor technical implementation and even sour working relationships between designers, directors, and other production professionals.

Some lighting experts work very intuitively. Without an artistic vision, work can become rote, reduced to a series of buttons and saved programs. Guided by design, lighting professionals can make fast, creative decisions required by a last-minute set change or other challenges.



Battle on the Sand Cliff Deck

Kà facts and figures

Kà is the "heroic journey of love and conflict, set within ever-changing theatrical landscapes that conjure an entire empire on stage" [1].

The set

- Entire performance area measures 100 x 25 x 36 m (width, height, depth)
- Conventional stage replaced by a gray 8 m deep pit and two giant floating platforms (below) and five smaller lifts and platforms
- Main platform: 50-ton Cliff Deck, measures 8 x 15 x 2 m, rotated 360° and tilted from flat to 100°, operated with a gantry crane and hydraulic pistons
- Secondary platform: Tatami Deck, measures 9 x 9 m, located upstage of the Sand Cliff Deck

The lighting

Kà uses nearly 2,700 dimmers and 3,000 light fixtures. Nearly half the fixtures are located out in the theatre – closer to the audience.

- Household bulbs
- 5,000-watt Fresnel lanterns
- Fake fluorescent lights
- Rope lights
- Metal halide lamps
- LED pop lighting
- Electronic candles with LEDs
- Strobe lights
- Beam lights (some are HMI)
- LED wash fixtures
- Theatrical and industrial fixtures

"With the lighting [for Kà], we wanted to provoke a reaction theatre, to make it like walking into an environment. It needed to include the essence of the show."

Luc Lafortune, lighting designer

[1] Cirque du Soleil press release. "Kà: The ground-breaking adventure by CDS at MGM Grand Las Vegas." https://www.cirquedusoleil.com/en/press/news/2005/ka-las-vegas.aspx, accessed September 23, 2014

Holst Memorial Lecture

Thursday 13 November **2014**

06

History of the Holst Memorial Lecture and Award

The Holst Memorial Lecture is held each year at the University of Technology in Eindhoven (TU/e), the Netherlands, with support from Philips Research.

The theme reflects an important contribution to the development of research and technology, in line with the idea advocated by Dr. Gilles Holst concerning the development of applied sciences, particularly mathematics and the natural sciences, for the benefit of industry on the one side and their implications for society on the other.

The Holst Lecture is given by an eminent scientist in a selected field of research. Candidates for the lecture and the associated Award are selected by a committee consisting of representatives of both Royal Philips Electronics and the University, under the chairmanship of the Rector Magnificus of the TU/e and the CEO of Philips Research.

The audience is made up of university staff and students, representatives from industry, and other guests with a general interest in science and technology. To honour the guest speaker, a symposium with invited speakers precedes the Memorial Lecture.

After the Lecture, the Rector Magnificus presents the Guest Speaker with the Holst Memorial Lecture Award, a special bronze medal designed by Dutch sculptor Jos Reniers.

Gilles Holst (1886-1968)

As an academic, Gilles Holst is best known for the essential part he played at the University of Leiden, the Netherlands, in the discovery of superconductivity by Nobel Laureate H. Kamerlingh Onnes.

However, Holst is first and foremost remembered as the founding director of the famous 'Nat Lab', the Philips Physics Laboratory in Eindhoven, where he worked between 1914 and 1946. Gilles Holst was also chairman of two committees that were instrumental in establishing the University of Technology in Eindhoven in 1956.

07

List of Holst Memorial Lecture Award Recipients

The first Holst Memorial Lecture was given in 1977 to commemorate the 21st anniversary of the founding of University of Technology. Since then the speakers have included:

1977 **Dr. Alexander King,** Director OECD, Paris, 'The role of the engineer and the engineering sciences in future society'.

1978 **Prof. Dr. Cristopher Freeman,** University of Sussex, Brighton, UK, 'Technology and employment: long waves in technical change and economic development'.

1979 **Prof. Dr. Carl Friedrich Von Weizsäcker,** Max Planck Institute, Starnberg, Germany, 'Langfristige Energiepolitik als Beispiel technischer Zukunftplanung'.

1980 **Prof. Kevin Lynch,** MIT, Cambridge, USA, 'What is a good city? General theory of good city form; a new try at an old subject'.

1981 **Prof. Dr. Hendrik B. Casimir,** Philips N.V., Eindhoven, the Netherlands, 'Gilles Holst, pionier van het industrieel onderzoek in Nederland'.

1982 **Dr. Michiyuki Uenohara,** Nippon Electric Co, Kawasaki, Japan, 'The Japanese social system for technological development; its merits and demerits'.

1983 **Prof. Dr. Joseph Weizenbaum,** MIT, Cambridge, USA, 'The place of the computer in our world'.

1984 **Prof. John M. Ziman,** F.R.S., Imperial College London, UK, 'Doing my own work: the individual in collectivized science'.

1985 **Prof. Ilya Prigogine,** Nobel Laureate, The Solvay Institute, Brussels, Belgium, 'Exploring complexity from the intemporal world of dynamics to the temporal world of entropy'.

1986 **Prof. Sir Hermann Bondi,** F.R.S., Churchill College, Cambridge UK, 'The application of satellites in connection with the environment'.

1987 **Prof. Dr. Dick Swaab,** Dutch Institute for Brain Research, Amsterdam, the Netherlands, 'De klok in onze hersens'.

1988 **Prof. Dr. Abraham Pais,** Rockefeller University, New York, USA, 'Einstein's influence (the impact of Einstein's relativity theory)'.

1989 **Sir John Maddox,** Nature Magazine, London, UK, 'How true is the promise of science?'.

1990 **Prof. Dr. Cornelis M. Braams,** FOM-Institute Plasma Physics, Nieuwegein, the Netherlands, 'Kernfusie in historisch perspectief'.

1991 **Prof. Dr. Philippe G. de Gennes,** Nobel Laureate, ESPCI, Paris, France, 'Bubbles, foams and other fragile objects'.

1992 **Dr. Arno A. Penzias,** Nobel Laureate, AT&T Bell Laboratories, Holmdel, USA, 'The future of knowledge intensive industries'.

1993 **Prof. Dr. Henk C. van de Hulst,** University of Leiden, the Netherlands, 'Het astronomisch spectrum'.

1994 **Prof. Dr. Donald P. Greenberg,** Cornell University, Ithaca, New York, USA, 'Imaging and the electronic age'.

07

1995 **Prof. Dr. Hubert Curien,** Université Pierre et Marie Curie, Paris, France, 'Big instruments and big programmes for research; where is the limit?'.

1996 **Prof. Dr. Serguei P. Kapitza,** Russian Academy of Sciences, Moscow, Russia, 'World population growth and technology'.

1997 **Prof. Dr. Nicholas Negroponte,** MIT, Cambridge, USA, 'Why Europe is so unwired'.

1998 **Prof. Dr. Alan J. Heeger,** Nobel Laureate, University of California, Santa Barbara, USA, '20 years of research into conducting and semiconducting polymers; is it worth the effort?'.

1999 **Prof. Dr. H. Koenraad Hemker,** University of Maastricht, the Netherlands, 'Een bloedstollende geschiedenis'.

2000 **Dr. Rod C. Alferness,** Lucent Technologies, Holmdel, USA, 'Optical networks, enabler of the communication revolution'.

2001 **Dr. John L. Hennessy,** Stanford University, Stanford, USA, 'Directions and challenges in microprocessor architecture'.

2002 **Dr. Harold G. Craighead,** Cornell University, Ithaca, USA, 'Nanostructures for mechanical and biological applications'.

2003 **Dr. Sanjiv Sam Gambhir,** Stanford University, Stanford USA, 'Imaging diseases with molecular detectives'.

2004 **Sir Richard Friend,** FRS, University of Cambridge, UK, 'Plastic Electronics: new science, new technology, new products and new markets'

2005 **Dr. J. Craig Venter,** the Venter Institute, Rockville MD USA, 'From the Human Genome to Environmental Metagenomics'

2006 **Prof. Dr. Peter Carmeliet,** KU Leuven en VIB, Belgium, 'The neurovascular link of A. Vesalius revisited'

2007 **Prof. Dr. Henk van der Vorst,** RU Utrecht, the Netherlands, 'Men and Computers: an Upward Spiral'

2008 **Prof. Dr. Shuji Nakamura,** University of California Santa Barbara USA, 'Current and Future Status of Sold State Lighting'

2009 **Prof. Dr. Rutger A. van Santen,** Royal Academy of Arts and Sciences professor at TU/e, 'Energy, Catalysis and Society'

2010 **Dr. Denis Le Bihan,** Neurospin, Gif-Sur-Yvette, France 'Water: from Brownian Motion to the Mind'

2011 **Prof. Donald E. Ingber MD, PhD,** The Wyss Institute, Harvard University, USA. 'From Cellular Mechotransduction to Biologically Inspired Engineering'

2012 **Russel Foster, Bsc, PhD,** FRS, The Nuffield Laboratory of Ophtalmology, Oxford University, UK, "Light and the Rhythm of Life'

2013 **Cherry A. Murray, PhD,** Dean Harvard School of Engineering and Applied Sciences, 'Engineering for All'

2014 **Dr. ir. Robert Cailliau,** Former staff member CERN, 'The Web Adventure'

Imprint

Holst Committee
Candidates for the Holst Memorial Lecture 2014 were selected by the Holst Committee under the joint chairmanship of Hans van Duijn, rector magnificus Technische Universiteit Eindhoven (TU/e) and Henk van Houten, General Manager Philips Research. Secretary to the Committee: Joep Huiskamp (TU/e).

Members of the Scientific Organizing Committee 2014
Sjoerd Mentink (Philips Research), Kees van der Klauw (Philips Research), Ingrid Heynderickx (TU/e), Emile Aarts (TU/e).
Secretary to the Committee: Joep Huiskamp (TU/e).

Publication and distribution
The editors wish to thank Robert Cailliau, Cees Ronda, Luc Lafortune, Robert Karlicek and Steve Fotios for their kind cooperation.
This edition was edited by Joep Huiskamp (TU/e).
Text: David Hegarty, KPUNKT Technology Marketing
Graphic Design: Martijn Pouwels, KPUNKT Technology Marketing
Project Coordination: Linda van Gend, KPUNKT Technology Marketing

Illustrations
Illustrations have been published with the permission of the speakers.

On the 17th of November, 2014, Eindhoven University of Technology hosted the Holst Memorial Lecture and Symposium, with the support from Philips Research. This cooperation is fitting for an event commemorating Gilles Holst. He both founded the Philips Physics Laboratory in Eindhoven, which later became Philips Research, and was instrumental in founding the Eindhoven University of Technology.

www.holstmemoriallecture.nl