Modern Theatres –

Stage Engineering Systems from 1950 to the present

By Mark Ager

Stage Engineering systems – the equipment and systems used to move scenery, people or other objects – have been part of theatres and opera houses for many centuries.

The discovery of electricity in the late 19th Century gave rise to the new power of the electric motor. At around the same time hydraulic systems came into use. These new power sources took on the role of driving the heaviest pieces of stage machinery but there was little change beyond that – positioning of the scenery was performed by human hand/eye co-ordination.

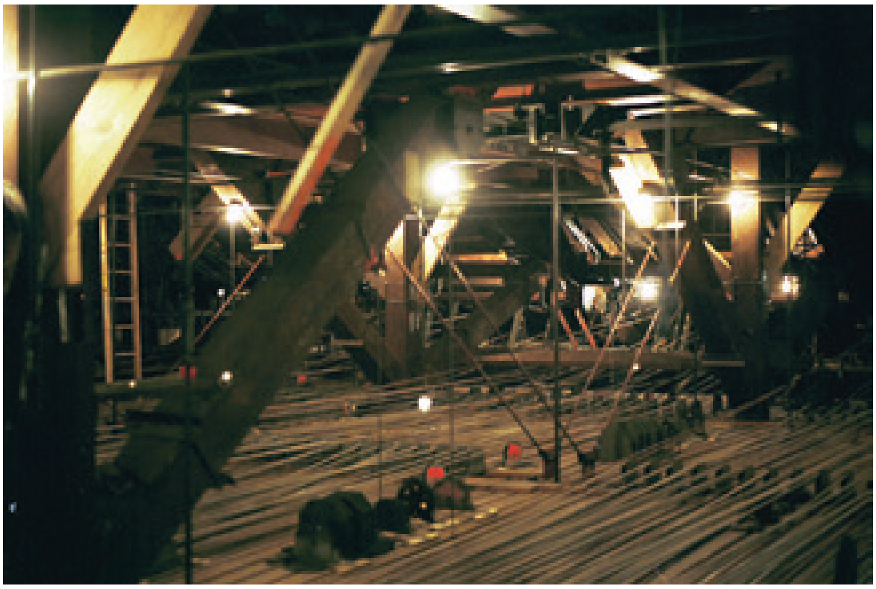
This age-old system has, in the last 70 years, fundamentally changed due to a single invention, and the consequences and developments from that invention.

In December 1947 John Bardeen, Walter Brittain and William Shockley demonstrated the first working transistor at Bell Laboratories. The transistor provided the key to unlocking an age of compact and affordable computing power that has hugely influenced and changed the theatre engineering industry, much as it has many other walks of life, to a point that the technology used on stage today is unrecognisable to that which existed at the beginning of the 1950s.

What the computer allowed was the ability to automate movements, enabling scenery battens or lifts to be moved into position without human intervention. Prior to this the position of each moving element (or axis) needed to be observed by an operator which severely limited the movements that could be achieved. There were some examples of linking mechanisms together (by mechanical or simple electrical means), but mostly this consisted of power amplification rather than allowing autonomous movement.

The computer provided the ability to control the axis, (or multiple axes) and run to a pre-programmed position, without the need for human intervention during the motion. This gave a single operator the ability to move multiple axes to different positions and use different speeds. Further it enabled automated control of the relative positions between several axes whilst they moved. In today's modern theatre, multiple axes move together in intricate and complex motions and can also be linked to lighting, video, and sound systems, to create a wealth of possibilities that would have been unthinkable under purely human control. Further, the ability of the computer to 'think' faster has led to a significant increase in both the loads and speeds that can be moved in live performance.

Pre-1950 the flyman could move a manual counterweight flying set of up to 3-500kg at speeds of up to 1.5m/s. Modern control systems can move multiple tonnes, safely with speeds of up to 4 or 6 m/s with pinpoint positioning accuracy – a feat that simply could not have been achieved using manual positioning systems. The computer has led to a large increase in the scale and complexity of mechanical engines used in the theatre.



Grid and manual flying at the Academy of Music, Philadelphia PA USA Courtesy of Bill Sapsis

Met Opera (Built 1963-66)

The first truly automated power flying system in the USA was designed and installed by the Peter Albrecht Company and installed at the new Metropolitan Opera House in 1965. In contrast to the purely manual (by eye) positioning that had gone before, position is achieved through an electronic system.

Multi-turn analogue potentiometers indicate the current position of the fly bar. The required position for the fly bar was then dialled in on a second multi-turn potentiometer mounted at the control desk. An electronic analogue comparator within the control system compared the required and actual position and then slowed and stop the bar as it approached the correct position. This allowed for a number of bars to be run at the same time by a single operator. A further intelligent mechanism 'The Master System" allowed 2 or more bars to be run in synchronisation so that they could be used together to lift larger pieces of scenery. This electro-mechanical system provided for multiple modes of linking and synchronising axes together.

At the time, the cost of drives was such that purchasing one per motor was unaffordable because each drive was assembled out of individual components. Consequently, a manual patch system was installed between drives and motors which allowed the user to select which motors (around 160) to move from which drive (around 32).

The Met Opera power flying system represented the state of the art at the time. It was apparently developed in conjunction with the US military which meant the site was in lock down during the installation. It is incredible, and a tribute to those that operate it, that the system is still in use to this day, more than half a century after it was designed. However, it was not a truly computerised system, as it used custom electronic and electromechanical systems to provide the required functionality. The first truly computerised system was installed in the UK in the late 1970s.

Metropolitan Opera, NY, flying control desk Courtesy of Jeff Mace, Metropolitan Opera

National Theatre UK (1976) – (Olivier Stage) Power Flying system

The National Theatre was the first to use a true computer (in this case a Digital Equipment Corporation PDP11-35 computer) to control the stage systems.

The design of the Olivier Theatre suggested the need for a 3-dimensional flying system, based on point hoists, rather than the traditional cross stage bar. This in turn produced a requirement for a hoist control system that would allow multiple hoists to be run together in synchronisation. Due to clever rigging the hoists could be positioned at any point along a track system, by adjusting the hook clamp on stage.

Both the Metropolitan Opera, and the National Theatre systems were custom built for specific theatres, with all the research and development costs taken within the project. The dream was for standardised systems (much like lighting and sound control desks) that would be replicated in multiple theatres, thereby reducing costs by spreading the research and development investment over multiple implementations.

The first generation of companies with that goal in mind began to appear in the 1980s with Hoffend in the USA, Bytecraft in Australia, and shortly after Nobel electronics in Norway. The first systems were based around a single computer, much as the National Theatre's had been. However, the challenge of controlling multiple motors at the same time is that each hoist needs a lot of monitoring/processing power to ensure that it moves and positions accurately. Some early systems struggled with the computational requirements of controlling multiple hoist movements.

An alternative that started to appear in the 1980s was to use a small computer or microprocessor for each individual motor. The challenge then was to network these multiple processors in a suitable manner such that they could all work collaboratively and respond to user commands in 'real' time.

In many parts of the world these microprocessor systems were borrowed from industrial control systems which were themselves taking on microprocessor technology. Such systems had mixed success, dependent both upon whether the underlying hardware/processing technology was able to provide the flexible control required within a theatre environment, (very different to industrial control) and also whether the user interface was programmed to provide the flexibility required to meet the unique demands of working in a theatre environment rather than those of traditional industry.

Most of the first-generation systems were installed in large opera houses, and national venues – created by a demand primarily from governments to have the newest and the best. However, through the 1990's other drivers for automation take up began to appear.

Richard Brett at the National Theatre, London power flying control desk
Courtesy of the Brett Family

West End and Broadway Musicals

In the UK and the USA, the commercial demands of the West End and Broadway musicals were drivers for ever more spectacular shows and (particularly in the case of Broadway) keeping staffing costs down. This led to a rapid growth in the use of standard automation systems and a raft of innovations such as multi-dimensional movements. The fast turnaround nature of these shows helped with the rapid development in the technology.

Automation moves until this time had largely been one dimensional (with the exception of a few revolve/wagon drive solutions). However, the desire for ever more spectacle resulted in increasingly complex move sequences.

Martin Guerre (1996) was the first use of 2 dimensional trucks on stage. The first 3D performer flying system was used on *Witches of Eastwick* in London (2000) followed by an even more complex six degrees of freedom motion system developed for *Chitty Chitty Bang Bang* two years later.

Dutch Experience

In 1999 the Dutch government determined that the traditional counterweight system was a big health risk for stage staff and the law banning such systems became effective in January 2004. This had become an issue because of the typically one/two-day touring structure, hence shows being loaded in/out of venues 3 to 4 times a week, resulting in back injuries way above the average for the population. As a result of this over a ten-year period virtually all the flying systems in theatres in Holland (over 100) were automated.

Germany

In the 1950s, Prof. Walter Unruh effectively defined the perfect form for an opera house stage and fly tower. Unruh designed the MET and Sydney Opera Houses,

having developed and applied the principles for the perfect stage as defined by Friedrich Kranich in his ground-breaking work “Theatertechnik der Gegenwart“ from 1929. This included a cruciform stage, with side stages, wagons, lifts etc. Which by its nature demanded stage engineering and automation. This linked with the desire for opera in Germany and the engineering prowess of the country led to a big take up of engineering systems within the theatre.

However, the innovation was hampered by safety standards that for some time forbade the use of cross flying (i.e. scenery bars flying up and down at the same time) and speeds above 1.2 metres/second. Further, there was a desire to ensure the absolute safety of the control system – which could not be guaranteed by a single processor. For this reason, custom control systems with two processors were developed to control and monitor each motor, with internal voting to ensure that each came up with the same solution for the control. Any error between the two processors would shut down the system. This limitation resulted in custom systems being designed that were limited in capability. Complex movements and links with other systems were not explored.

Modern Circus

Cirque du Soleil started as a touring troupe of circus performers in 1984 using minimal technology. However, beginning with Mystère in 1993 they started putting on increasingly lavish productions in custom-built theatres in Las Vegas. The commercial nature and success of the operation meant that they had increasingly large budgets to realise their vision, which reached a pinnacle with KÀ in 2003.

KÀ – Cirque du Soleil (2003- present)

This show, encompassed engineering on a huge scale, enabled by stage automation.

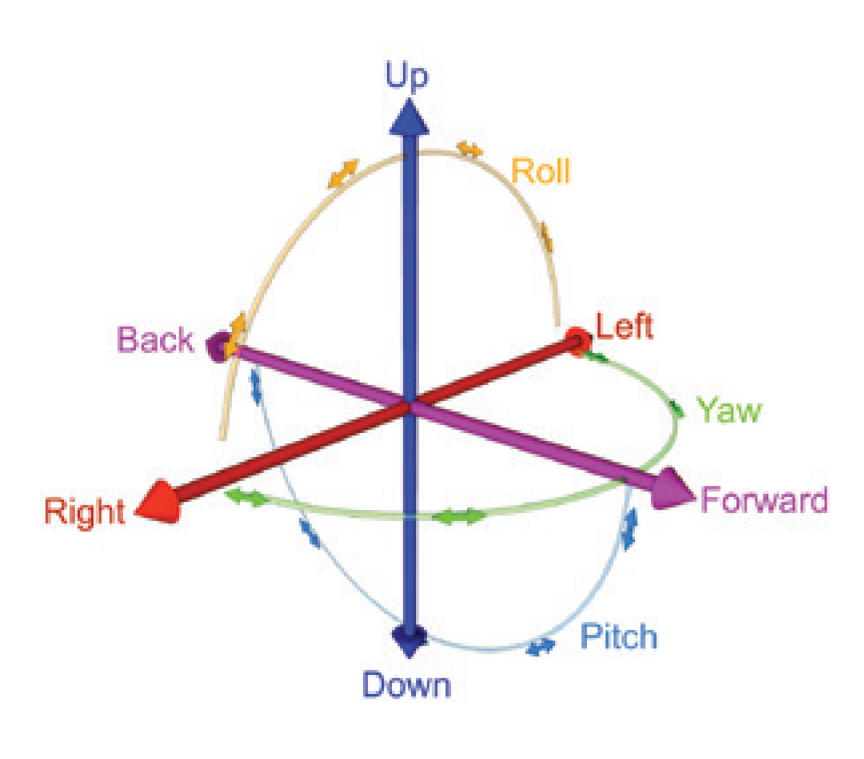


Diagram showing the six degrees of freedom Pg 16 Courtesy of TAIT

The main stage – the Sand Cliff deck – comprises a 60'x40' platform that has the ability to both raise and lower with a travel of 60', tilt between horizontal and vertical and continuously rotate. The automation system controls over 200 axes, which, unlike in more traditional venues, move multiple times every night, often in complex cueing sequences, controlled by multiple (4) operators. The whole impetus and reason for the installation was to produce the spectacular.

Concert Touring

Since around 2007, the concert touring industry has been a big driver for innovation.. Not only do these tours demand complex moves, but also to link seamlessly with other media (lighting, sound, and increasingly video) used within the show.

Taylor Swift's '1989 World Tour' (2015), showed how commonplace and complex these movement sequences and links have become, with a profiled bridge moving in three dimensions, linked to a 3D flying camera, the camera position being kept in the correct relative position to the performer, whist the singer moves in complex 3D profile around the venue. Distance and location information is fed from the automation system to the video system to allow the singer to be kept in shot and focus.

Innovation in Stage Engineering

The first ten years of the 21st century saw the automation of stage systems becoming standardised and mainstream, with many of those ground-breaking effects (often created outside the traditional theatre industry) becoming commonplace, and an increased take-up both in fixed venues and touring theatre. There has also been the emergence of standard winches from a number of manufacturers.

Despite this huge change in automation control systems there has been little change in the engineering systems that they control. These systems have remained largely as they were 60 years ago – at least in the traditional theatre environment.

Over stage

There has been little change in the format of over stage systems in the last 150 years. True, far more systems have been automated, and motorised since the 1950's, and the loading capacity, and speed of these system have increased enormously (from 200kg to 1000kg and more, with speeds of 2m/s (manual counterweight 1.5m/s)) but most theatres flying systems still consist of a series of bars or battens that extend back across the stage, spaced at 4-8" centres. This despite the fact that this layout could be considered more appropriate to the cloths and painted backdrops that were in fashion a century ago, rather than the solid angled sets that populate today's stages.

There have been very few notable exceptions. The Olivier Stage, in addition to its ground-breaking automation system, also employed a system of 170 point hoists rather than battens that could be positioned simply anywhere around the stage. The Theatre de la Monnaie in Belgium mixes point hoists, and battens (both powered and counterweight).

This is the impact of touring work. Whilst 99% of all theatres have the traditional batten system installed, it is difficult to see how this system might change – though it is arguable that it is no longer appropriate in an age that technology offers multiple opportunities.

The exception is in houses specifically built for shows, mainly by the likes of Cirque du Soleil and Franco Dragone. Here the rigging plots have become freeform, with an eclectic mix of point hoists and bars at all curves and angles – specific to the needs of a particular performance. They have also introduced the idea of winches on trolleys, travelling on both straight and curved tracks to provide

Flying car in Chitty Chitty Bang Bang demonstrating six degrees of freedom Courtesy of TAIT

an alternate way to deliver both performers and scenery into the stage space. This idea has recently started to be taken up by more traditional theatre forms.

Under stage systems

Touring has also meant that there has been little innovation in the under-stage systems, with no lift system that is standard enough to ensure that touring productions can rely on a lift (or even the means to install a lift) in each venue on the route.

Horizontal moves on stage, first provided by manual, and then motorised, tracking/winching systems have become prevalent in many larger musical productions since the 1980s. These systems employ a guide track with a skate that can be used to pull multiple scenic elements on and off stage and they have become a standard method of delivering scene changes in modern theatre. The desire to tour these productions has led to the rise of the 'Show Deck' a 150-200mm high deck that contains the tracks and other automation elements for the production. Unfortunately, the majority of theatres (even those built since the 1980's) do not allow for easy integration of show decks. Raising the stage floor by 200mm, significantly adversely affects the sightlines from the stalls seating. This has resulted in productions re-raking the auditorium to accommodate the production, when a lower stage with a simple lift would have allowed simple transfers.

The Future

The last 70 years have produced a revolution in the control of stage engineering systems – enabling them to move with a degree of complexity, speed, and with loads never previously imagined. At the start of the period the new technology was used to drive traditional venue formats, however we are beginning to see new forms of venue that are built around, and reliant on these new engineering technologies. The increasing use of video – both in projection, and fixed and moving LED screens – has further changed and merged the real and the virtual worlds into a single entertainment environment on a different scale, and in changing formats to that imagined previously, where close-ups of an individual performer are merged with vast scenic panoramas within the stage space.

In a similar scenario, when factories first started using electric motors to replace the steam engines/water mills of previous eras they were initially used in a very similar manner to the previous power systems, and it took 50 years for their benefits to affect the design and layout of factories. Perhaps the same will happen with theatre buildings and stage layouts?

Bibliography

ABTT Sightlines Spring 1979 – The Olivier Power Flying System by Richard Brett