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The Building of the Crystal Palace

The Crystal Palace was built in London for the Great Exhibition of 1851. To put this in historical perspective, this is just 35 years after the Battle of Waterloo brought an end to the Napoleonic wars, and 60 years before Henry Gantt began his work¹.

A Brief Synopsis of the Building

The Crystal Palace, was a building the size of a modern shopping mall: 1848 feet [563.3 meters] long, 408 ft [124.4 m] wide and 108 ft [32.9 m] high, with a roofed area of 772,784 square feet [71,794m²] about 19 acres [7 Hectares]. The sketch plans prepared by Joseph Paxton were approved on the 11th June 1850:



Sir Joseph Paxton's original sketch on blotting paper of the Crystal Palace. 11 June 1850. Fig.1 The famous 'original design'

With the 'design' approved, tenders were sought from industry and the design proposal from Fox, Henderson and Co accepted. Most of the iron work was made by Messrs Cochrane & Co, of Woodside Ironworks and Mr Robert Jobson, of Holly Hall Ironworks. The 293.655 sheets of glass used in the construction were made by Chance Glassworks of Smethwick. Work started on the 15th July 1850, possession of site was granted on the 30th July, the first column was erected on the 26th September and the formal contract signed on the 31st October.

¹ To see the events discussed in this paper in a comprehensive historical timeline download *Project Management - A Historical Timeline*: <u>https://mosaicprojects.com.au/PDF_Papers/P212_Historical_Timeline.pdf</u>



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The initial construction in Hyde Park required an existing row of elm trees to be preserved within the structure:



Fig. 2 These main barrel vaults were the only part of the structure made from wood.

The design was highly modular, based on the largest sheet of glass then available measuring 10 inches wide by 49 inches long. And the construction process was highly mechanised with substantial off-site fabrication².



Fig. 3 The exhibition in full swing.

² For more on the construction see: <u>http://en.wikipedia.org/wiki/The Crystal Palace</u>



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8 ¹/₂ months after the start, the Great Exhibition opened on the 1st May 1851. The construction was substantially complete after 5 months (and consumed close to 1/3 of the glass manufactured in Britain that year). The installation of the 14,000 exhibits overlapped the completion of construction through to the opening. Exhibitors came from all regions of the UK, its dominions and dependencies, and 44 other nations.

The event was a fantastic success with a total attendance of 6,039,195. By way of comparison, the total population of London at the time was estimated at 2,350,000! The total cost of the exhibition was £339,742 and it made a profit of £186,000. The *Royal Commission for the Exhibition of 1851*, which was originally appointed in 1850 to organise the Exhibition, was continued in perpetuity to spend these profits.

Prince Albert decreed the money was to be used to "increase the means of industrial education and extend the influence of science and art upon productive industry". The Commissioners' first act was to purchase 96 acres of land in South Kensington, and over the next fifty years they established the Victoria & Albert Museum, Natural History Museum and Science Museum; the Royal College of Art and Music; Imperial College London and the Royal Albert Hall. Although the museum sites were sold to the government in the late 19th century, the Commission remains the landlord of much of the land, and uses its income to fund research fellowships aimed at encouraging bright, early-career scientists to develop their research. The current distributions are some £2 million per year.

The name Crystal Palace was coined by Punch Magazine, adopted by the general public during the exhibition period and remained associated with the building when it was sold to a private company and moved from its location in Hyde Park to a new site in the South of London. The rebuilt structure was located to a hill in the suburb of Sydenham as a venue for other shows and exhibitions.



Fig. 4 The rebuilt Crystal Palace in Sydenham (suburb now called Crystal Palace)



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The building was destroyed by fire on the 5th December 1936 (an event witnessed by my mother).



Fig. 5 "This is the end of an age" Sir Winston Churchill

To appreciate the significance of this building, the suburb it was located into, the local football club and the parkland that housed the recycled building all retain the name Crystal Palace³. One of the original exhibits in the parklands remains intact, the Crystal Palace Dinosaurs, a series of sculptures of dinosaurs and other extinct animals, incorrect by modern standards, but representing scientific understanding of 150 years ago. All of the dinosaurs are permanently protected and preserved as Grade 1 Listed Structures⁴.



Governing and Controlling the Construction

My interest in this project is very much focused on the project controls and governance aspects of the management of this remarkable endeavour; and during a trip to the UK in mid-2013, I spent an enjoyable, but frustrating day browsing through the reports of the Royal Commission responsible for the whole of the exhibition and its legacy.

⁴ For more on the Crystal Palace Dinosaurs see: https://en.wikipedia.org/wiki/Crystal Palace Dinosaurs



³ YouTube video highlighting the Crystal Palace, the people involved and the exhibition can be seen at: <u>https://youtu.be/lunN7Ob_R9k</u> and <u>https://youtu.be/CzvHv9CmdKQ</u>



The Victoria and Albert Museum holds copies of the five reports of the Royal Commissioners responsible for constructing the exhibition buildings and facilities and staging the Great Exhibition. Reading through them, looking for information on the management of the construction process several aspects stand out. The first is, the first report was not written until after the exhibition finished. And the major disappointment was the fact the construction was contracted to the engineering firm Fox, Henderson and Co, and as a consequence, the actual construction management processes were not documented by the Royal Commissioners.



Fig. 6 The very fragile nature of the report prevented a better image being captured. However, the use of graphical images to convey complex data is apparent, as demonstrated by this high-quality chart detailing attendance against a range of daily factors. The chart clearly demonstrates the ideas embedded in William Playfair's *Atlas* of 1801 were understood and in general use (Royal Commissioners are rarely adventurous). The various diagrams include line graphs, histograms and date scales but unfortunately only relate to the period the exhibition was open to the public.







Fig. 7 For comparison, a chart by William Playfair from 1821.

Detailed records of the construction process are also reported by the commissioners. Information on the construction workforce on site indicates sophisticated record keeping, as can be seen from the table below, the workforce on site peaked at 2145, supported by many more off site engaged in the fabrication and transport of the component parts to Hyde Park.

	29	3,655 Panes.				
RETURN showing	the Num Erec	ber of MEN Pai etion of the Exhi	id each W	eek in Hyde I ling.	Park, in th	
Week ending	No. of Men. 30 57 60 43 50 56 86 128 293 467 590 808 847 1,938 1,935 1,935 2,129	Week ending- 1850 6 December 13 ,, 20 ,, 27 ,, 1851 3 January 10 ,, 17 ,, 24 ,, 3 February 14 ,, 21 ,, 28 ,, 7 March 14 ,, 21 ,. 28 , 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 24 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 24 ,. 21 ,. 24 ,. 21 ,. 22 ,. 24 ,. 21 ,. 24 ,. 21 ,. 24 ,. 21 ,. 22 ,. 23 ,. 24 ,. 24 ,. 21 ,. 24 ,. 21 ,. 22 ,. 23 ,. 24 ,. 24 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 21 ,. 21 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 21 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 24 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 21 ,. 22 ,. 23 ,. 24 ,. 21 ,. 21 ,. 28 ,. 21 ,. 28 ,. 21 ,. 28 ,. 21 ,. 28 ,. 21 ,. 28 ,. 21 ,. 28 ,. 21 ,. 21 ,. 28 ,. 21 ,. 21 ,. 28 ,. 21 ,. 21 ,. 28 ,. 21 ,. 21,	No. of Men. 2,118 2,118 2,074 2,035 2,145 2,098 1,758 1,653 1,417 1,333 1,110 1,244 1,353 1,974 2,030 2,071	Week ending- 1851 4 April 11 i, 18 i, 25 i, 2 May 9 i, 16 i, 23 i, 30 i, 6 June 13 i, 20 i, 4 July 11 i, 18 i, 25 i, 2 May 9 i, 13 i, 20 i, 20 i, 13 i, 20 i, 21 i, 22 i, 21 i, 22 i, 21 i, 23 i, 20 i, 2	No. of Man. 2,133 2,163 2,163 2,147 2,149 1,097 541 442 369 442 369 216 153 153 153 153 153 153 153 153	

Fig. 8 Record of the on-site workforce.



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Recognising the risks associated with using relatively untried technologies in such a monumental structure, quality control was given a very high priority. Inspectors and superintendents were appointed and quality control processes included stress testing components and load testing foundations implemented.

DIRGT REPORT OF COMMISSIONERS. and Chairman to the Building Committee, to undertake the arduous duty of general control. As officers acting under and responsible to him, the gentlemen who had been nominated by the Building Committee to assist them in the preparation of their drawings, &e, were reappointed, it being understood that the division of about between them should be as follows :--Mr. Wild to make himself responsible for the engineering details, Mr. Owen Jones for the decoration, and Mr. Wyatt for the general building construction, fulfilment of contracts, extras, omissions, and the regulation of monthly accounts. In these departments each of those gentlemen acted during the erection of the Building ; Mr. Earie being employed as Clerk of the Works, and Mr. Harwood as Surveyor.

of the Works, and hill this root in the 30th of July, and a hoarding was Possession of the site was obtained on the 30th of July, and a hoarding was immediately erected, enclosing it. Great ingenuity was bestowed upon the adaptation of mechanical contrivances to diminish and expedite labour; but it would occupy too great space were the Commissioners to attempt an account of them.

Numerous experiments were made to verify the stability of the work, and the consequent safety of the public; every cast-iron girder on being brought on the ground was weighed and tested in a hydraulic press. The wrought iron trust were carefully examined, and their general conditions of efficiency determined by by experiment and theory. Some of the most questionable points of the foundation

Fig. 9 Commentary on Quality Assurance and supervision.

And as would be expected, the accounting of all costs, including the construction costs was precise to the Farthing (1/4 of a penny). The exhibition was a popular and financial success with a final profit of $\pounds 186,436$ 18s and 6d (in pounds, shilling and pence⁵). These profits were used to found the Victoria and Albert Museum and the Science Museum in London.

⁵ For a description of pre-decimal English currency see: https://www.royalmintmuseum.org.uk/journal/history/pounds-shillings-and-pence





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Project Governance & Control The Building of the Crystal Palace

a minute adopted by the building were sold for a higher sum of that if the materials of the building were sold for a higher sum of that estimated, the excess should be shared in equal proportions between the Commission and the contractors, the sum of 4,505% Is. 5d. was found to be repayable to us by Messrs. Fox, Henderson, and Co. out of the advance of 35,000%, in addition to the cancellation of a balance of about 5,000% remaining due by us on account of the original contract. On the payment to us, on the 11th November 1853, of the sum of 4,501%. Is. 5d. just mentioned, our accounts with the contractors were finally closed, and the necessary legal releases exchanged.

In our last Report we estimated the surplus that would remain Financial position of in our hands, after completing all the services immediately connected with the Exhibition at about 173,000*l*. (see Appendix A. to Second Report, p. 44). On making up the accounts, however, after those services had been finally adjusted, it was found that the Exhibition surplus was not less than 186,436*l*. 18s. 6*d*. A statement of the Receipts and Expenditure of the Commission, duly audited by the Governor and Deputy-Governor of the Bank of England, continued from the date of the former Returns, viz., the end of February 1852, and extending to the end of December 1855, is given in Appendix C. It will be seen from this Return, that in addition to the above-mentioned balance of 186,436*l*. 18s. 6*d*. carried forward to the credit of our Estate

Fig. 10 The final profit.

There is also an interesting recognition of the problems of building such a massive structure in such a short time from a very basic initial design. There were many improvements in the design implemented as the work progressed causing the builder to incur a substantial loss, particularly as finishing late was not an option.

The Commissioners recognised this issue and made provision to compensate Fox, Henderson and Co for the losses that could be justified. Their original tender was $\pounds79,800$, an additional $\pounds35,000$ was approved in November 1851 and a final payment of $\pounds4,505$ 1s 5d closed the accounts after taking into account the sale of the structure for $\pounds70,000$ to Fox, Henderson and Co for re-erection in what's now the suburb of Crystal Palace.

This understanding of the problem and willingness to work collaboratively to resolve it was no doubt helped by the presence of Sir William Cubit on the Commission. He owned a leading construction company and was a founder of what is now, 180 years later, the Chartered Institute of Building. However, for any Royal Commission to be able to properly dispense public money systems needed to be in place to properly quantify and cost the consequences of the changes needed to complete the building. This suggests sophisticated cost accounting processes within the building company as well as the Royal commission.



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THIRD REPORT OF COMMISSIONERS. 15 It is obvious that the receipt by the contractors of the above- Final settlementioned sum of 70,0001. for the materials of the building in accounts lieu of the 33,2501. at which they had been valued as old mate- with Messrs. lieu of the 33,2501. at which they had been valued as old mate- with messes, Fox, Hen-rials, was calculated to relieve them entirely from the pecuniary derson, and loss apprehended by them in connexion with their contract with us, and against which, as mentioned in our first Report (page xxx), we had undertaken to secure them; and it therefore became our duty to examine into their altered financial position as compared with that existing at the time when we advanced to them the sum of 35,0001. on the 7th November 1851, in consideration of their losses as then estimated. The result of our inquiries was that, acting on a minute adopted by us on the 14th January 1852, to the effect that if the materials of the building were sold for a higher sum than that estimated, the excess should be shared in equal proportions between the Commission and the contractors, the sum of 4,5051. 1s. 5d. was found to be repayable to us by Messrs. Fox, of the advance of 35 0001, in addition to

Fig. 11 Summary of the final account.

Conclusion

The reports of the Royal Commissioners show a very fine appreciation of governance. The objective of governance defined by Sir Adrian Cadbury Some 150 years after the Crystal Palace was built and the Great Exhibition staged is to "holding the balance between economic and social goals and between individual and communal goals. The governance framework is there to encourage the efficient use of resources and equally to require accountability for the stewardship of those resources"⁶. This defines governance as a pragmatic process focused on outcomes, not the blind imposition of undue process.

The Royal Commissioners demonstrably achieved those objectives by ensuring adequate compensation to the builder and ensuring the preservation of the Crystal Palace despite Parliament voting against retaining it in its original location. Flexibility was shown when needed allowing work to start months ahead of the contract signing which in turn allowed the exhibition to open on time but financial and quality controls were strict and effective.

⁶ For more on governance see: <u>http://www.mosaicprojects.com.au/WhitePapers/WP1033_Governance.pdf</u>



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Additionally, the results of the building contract strongly suggest the project was effectively controlled and managed. But unfortunately, whilst there are tantalising glimpses of sophisticated systems that could effectively manage extended off-site supply chains, large workforces and mechanised production; whilst dealing with the small tolerances allowed in modular cast iron, none of these have been preserved in the records of the Royal Commissioners. This is probably understandable given the Commissioners were the customer, not the builder and they had the overall responsibility of staging a massive event but it is disappointing.

The primary objective of my research⁷ was to identify the processes used by Fox, Henderson and Co to sequence, schedule, organise and manage the construction of a very large building in a remarkably short timeframe, with particular emphasis on time management. These records were not found and consequently, we still don't really know or understand how the major construction works of the 18th and early 19th century were managed.



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For more on the development of the concepts supporting the creation and use of bar charts see: <u>http://www.mosaicprojects.com.au/PDF_Papers/P182_The_origins_of_bar_charting.pdf</u>

For more on the development of scheduling in the 20th century see: https://mosaicprojects.com.au/PDF Papers/P042 History of Scheduing.pdf



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⁷ This paper is one of a series looking at the history of project management and project controls. The research was focused on filling the gap in knowledge of project controls during the industrial revolution.