

How the Great Pyramid was built
By Craig B. Smith
(A book review by R. Max Wideman, FPMI)¹

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Introduction

Knowing my passion for project management, a friend of mine sent me this book some time ago. However, on briefly flipping the pages and stopping to look at the dozen or so photographic plates in the middle, I concluded: "Oh well, just another book on the marvels of the pyramids in Egypt". And so I put it on the pile for later reading. How wrong I was.

In fact, the goal of author Craig B. Smith has been to document what he has discovered about what it must have taken to build this great historic monument some forty-five centuries ago. More significant perhaps is that, as his biography shows, Craig has a wealth of experience in managing the construction of large complex projects – in other words, construction program management in today's world.

As Craig explains it:²

"My interest lies in the engineering and construction of the Great Pyramid, and that coincides with my own experience and expertise. Since a substantial part of the pyramid is still standing – albeit it in a slightly damaged condition – it is possible to examine the construction and determine how some of the tasks were undertaken and executed. The same is true of the architecture and engineering and design.

"This type of 'forensic analysis' can only be carried so far, however, then one encounters a gap in solid information and findings. I decided to investigate this gap with the modern tools available to someone who plans and manages large public works projects. By means of this approach, bits and pieces of factual data can be assembled, and models can be developed that lead to a reasonably good understanding of how the project was implemented.

"Certain assumptions must also be made – for example, how many loads of soil or sand could an ancient Egyptian laborer haul per day? Fortunately, these things can be estimated with a good degree of accuracy. When we are less certain, a technique called 'sensitivity analysis' can be used to check how sensitive the final result is to the analysis. If large changes in the estimate do not change the final outcome, then the model is said to be insensitive to that particular parameter."

Craig goes on to observe:³

"Very little is directly known about the key players in the Great Pyramid drama – about their families, jobs, daily routines, frustrations, challenges. But based on my personal experience with large public works projects, I know that every day brings a little drama. Things don't go well, designs have errors, materials do not meet specifications or are not delivered on time, schedules slip, accidents happen, budget problems arise.

Communication and coordination are frequently cited as the major causes of problems. The need to resolve these issues is integral to every complex project. These same challenges undoubtedly faced the builders of the Great Pyramid. The details make the story more interesting, lend a degree of realism, and make the ancient Egyptians'

accomplishments all the more impressive."

As one who has also worked on large public works projects in the last 60 years, how true these remarks all sound. And the similar memories it brings back about the daily challenges we faced, not least of which were in managing the work force. While today we have a large variety of mechanical equipment to carry out a large part of the "labor" work that helps to accelerate progress, it seems that the principles of management have changed very little.

With this realization, I have now read the book with great fascination as it features so many aspects that I, myself, have experienced in my own career. I suggest that this is a must-read book for any young engineers contemplating entering the field of large construction projects.⁴ Or, for that matter, older engineers who will enjoy the authors' company.

About the author

Craig B. Smith is former president of Daniel, Mann, Johnson, Mendenhall, Holmes & Narver, a global engineering, architecture, and construction firm that has been involved in many major public works projects, including the renovation of the Pentagon before and after 9/11. He holds a Ph.D. in engineering from UCLA, where he was an assistant professor of engineering and assistant director of the Nuclear Energy Laboratory. His work on the Great Pyramid was featured on A&E's broadcasting station as *The Great Builders of Egypt* and on PBS's station as the *Lost Cities of the Pyramids*.

Book Structure



Figure 1: Max on a long-ago trip to the Great Pyramid at Giza, Egypt⁵

The content of this book is set out in ten chapters and four Appendices as follows:

1. Egypt during the Old Kingdom
2. Pyramid Evolution
3. A Tomb for a King
4. We Consecrate This Holy Ground
5. The Desert Comes Alive
6. Soaring towards the Heavens
7. Stair Steps to the Gods
8. The Workforc
9. The Construction Schedules
10. Life Everlasting

Appendices:

1. Egyptian Gods
2. Units of Measurement and Other Technical Data
3. Calculating the Number of Blocks in the Pyramid
4. A Primer on Program Management

Other:

Notes
Glossary
Annotated Bibliography
Illustration Credits

The book includes, as its centerpiece, sixteen high-gloss pages of color photographs and hand-drawn illustrations of tools, materials, and building techniques used by the ancient masters of construction.

The book has a total of over 300 pages and we are very happy to see that it also includes a Glossary of Terms. Most of these terms are those specifically needed to properly understand the building of a massive pyramid that took place some 4,500 years ago. Thus, the book is written in a clear style with ample illustrations and sketches to help the reader understand the author's research. For those in the business of managing large infrastructure projects, this book will be especially enlightening.

Introduction to project managing the Great Pyramid

Author Craig B. Smith opens his book with an Introduction, sub-titled *Quest for answers*. In this opening, he describes his visit to the site of The Great Pyramid at Giza as follows:⁶

"As I make my way up the hill, the sun is now directly overhead and in the brilliance of this light the pyramid seizes my imagination, a structural colossus vastly more extraordinary than I had imagined – *staggering* is the word for it." As an engineer and constructor, I have long been fascinated with how ancient civilizations constructed building, towns, and roads with limited tools and technology but with incredible skill. How they moved massive blocks of stone, erected immense structures without mortar, finished joints so fine that their crevices would not allow the intrusion of even a razor blade."

"But no monument has captivated the world more than the Great Pyramid. The most celebrated and enduring vestige of the remarkable civilization that emerged during the golden age of the pharaohs, it is a structure without equal. Roughly two-thirds the size of the Hoover Dam, it rises 146.6 meters on a base covering 5.3 hectares, and incorporates 2.6 million cubic meters of material (an estimated 2.3 million blocks of limestone and granite. And for more than 4,300 years it has stood as the tallest structure on earth – until the Washington Monument eclipsed it at 169 meters in 1885"⁷

As any topographical photo will show, there is more than one pyramid to explore, but not all are accessible. For example, as Craig enters Menkaure's pyramid, he muses:⁸

"I am struck by the fervid dedication that would have enabled a people to perform this backbreaking, mind-numbing labor – that would have prompted them to dig deep into the bedrock of this plateau with only crude tools at their disposal. These were people who had no pulleys, no wheels, no iron tools, no compasses – just chisels, saws, and drills made of copper, wood and stone. And yet they flawlessly designed, sited, and erected structures of precise geometric configuration and complex construction on an astonishing scale."

Craig goes on to explain how, in a flash of insight, he would explore the construction of the Great Pyramid by analyzing this tremendous work by applying the present-day process of 'work breakdown structure'. As he says:⁹

"Once this has been done, the resources needed to perform the project – materials and labor – can be determined accurately and the schedule to complete the work can be established. I can construct such a framework for the construction of the Great Pyramid by identifying and analyzing each of the steps it took to build the pyramid. [That is] from selecting and preparing the site to placing the last white casing stones on the Pyramid face."

But that's not all. Aside from working through his work breakdown structure, Craig also examines issues associated with establishing and managing a very sizable workforce to carry out the work.¹⁰

This book contains a massive amount of detail, so in a relatively short review such as this, it is impossible to do justice to the insights described. Especially since, in tackling the progressive stages of the work in the work breakdown structure, author Craig Smith also tackles each of the major project management specialty skills such as quality, time, cost, risk and so on.

In the following sections, we have picked a few extracts here and there by way of illustration. We hope this will inspire the reader to obtain a copy and give the book a much more detailed study.

Quest for answers

*Evolution of the pyramid*¹¹

"Early tombs featured a flat bench or platform – a *mastaba* – on top of the grave. These tombs evolved as more lasting forms of burial mounds. It is believed that the earliest pyramids evolved from mastabas and reflected this custom on a larger and much grander scale, fitting for the king. . . . Later, additional levels or "steps" were added to the mastaba. This stepped construction reached its apex with the Step Pyramid of Djoser at Saqqara.

[This pyramid] rose to a height of 60 meters and could have symbolized a stair step to the gods for this Third Dynasty ruler. We next encounter the early Fourth Dynasty pyramids constructed by Sneferu at Dahshur, which built upon Djoser's work and include the Bent Pyramid and the North – or Red – Pyramid. The latter is the first true pyramid constructed on a large scale and certainly served as the inspiration for Khufu's pyramid. After all, Sneferu was Khufu's father!

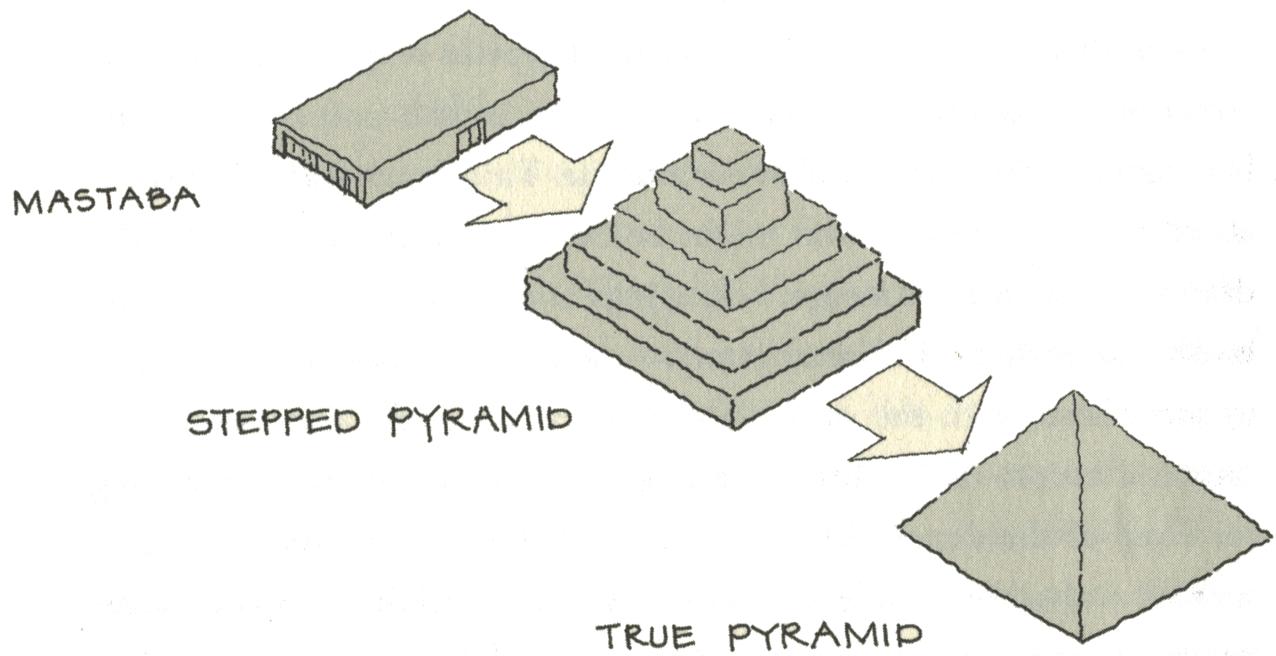


Figure 2: The evolution of pyramid design¹²

Measurements

"Egyptian mathematics were advanced, and we know that the ancient Egyptians could calculate areas, angles, and volumes. In fact, records of such calculations have survived from later periods. The Egyptians were able to carry out the accurate dimensioning and layout of large structures. They could calculate the weight of large objects and structures and determine the number of blocks required for a sloping embankment.

They used a decimal system and had methods of multiplying and dividing. Division was accomplished by breaking quotients into a series of sums of fractions – accurate enough for practical purposes. . . . Among the more sophisticated calculations the ancient Egyptians made was finding the volume of a truncated pyramid, obviously of great importance in determining the volume of material needed and the labor required, among other practical matters."¹³

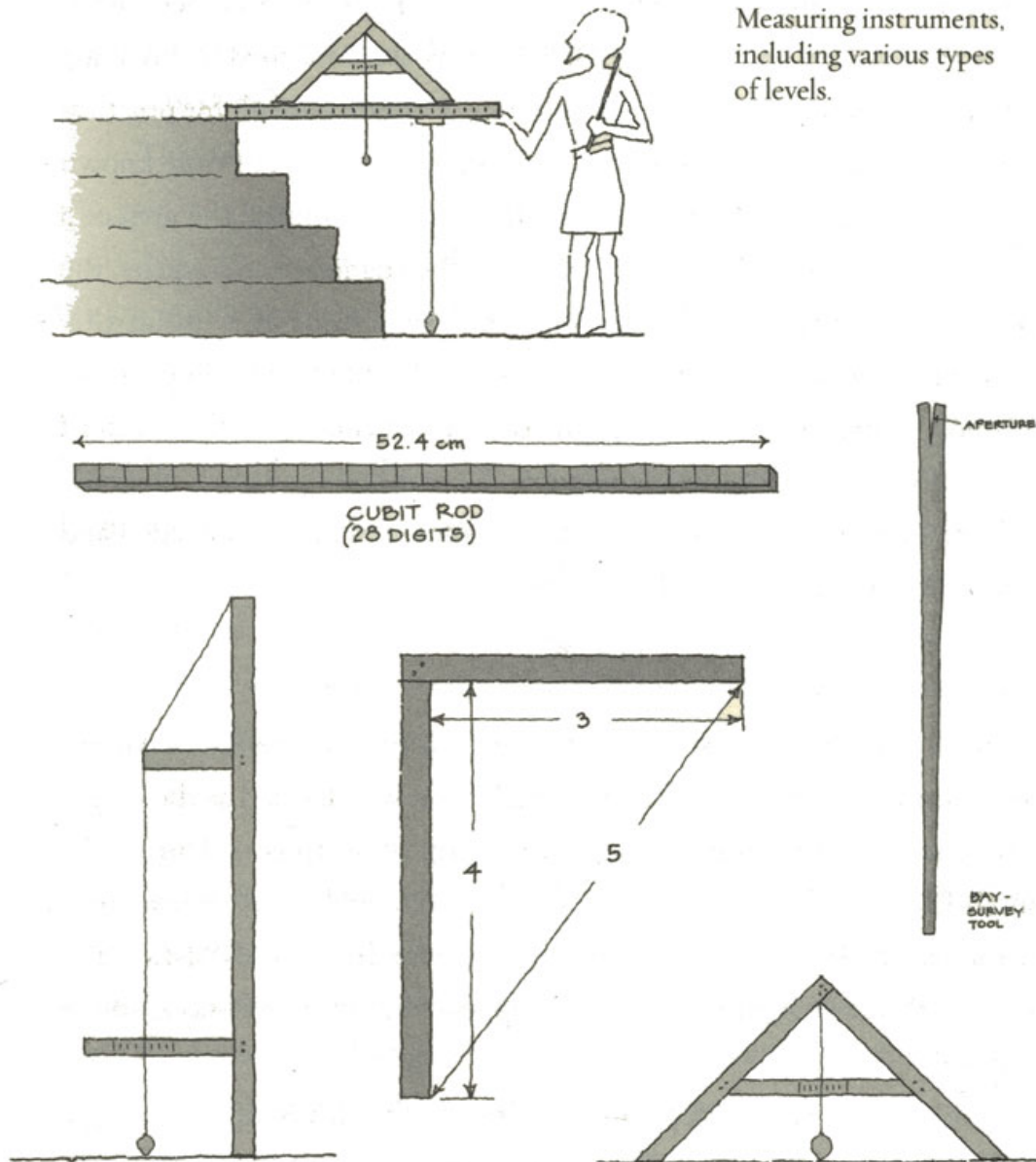


Figure 3: Measuring-instruments¹⁴

Tools

"Laborers used tools resembling mattocks or hoes for digging and woven reed baskets for hauling dirt and debris. Stonemasons used copper chisels and saws, drills, wooden mallets, wedges, wooden rollers, stone hammers, and smooth round balls of dolerite, a hard stone used to cut blocks of granite. A wide variety of woodworking tools existed, including mallets, hammers, drills, copper saws, chisels, scrapers and planes."¹⁵



Figure 4: Various building tools¹⁶

Transportation

"On land the ubiquitous donkey was used to transport goods. However, the main artery for transportation was the Nile River. Skilled boat builders and sailors, the Egyptians developed vessels ranging from small reed boats to oceangoing vessels. They sailed the Mediterranean coastline as far north as what are now Palestine, Lebanon, and Syria and crossed the Red Sea to Saudi Arabia. For transporting stone, they used sailing vessels and barges, some with capacities of at least 100 metric tons and perhaps as much as 1,000 metric tons. For larger loads, it is likely that rafts made of logs were assembled."¹⁷

Erection techniques

"No wheels are known to have existed during the Fourth Dynasty and the builders of Khufu's pyramid did not have wheels or pulleys for moving or lifting loads. Instead,

blocks of stone were levered onto wooden sledges and then dragged to the construction site by teams of laborers. Wooden levers were used to move loads over short distances, but for longer hauls it was necessary to construct ramps to bring blocks of stone up to the higher levels of the structure.

To place heavy roof beams, the room was filled with sand, and workers placed the beams (typically granite) while supporting them on the sand base. Then the sand was excavated. A similar approach was used to lower massive stones or a sarcophagus into a subterranean chamber, placing it on the sand and then removing the sand."¹⁸

Summary

There is no doubt that the logistics involved in preparing the site for the construction of the pyramids must have been extensive and challenging to say the least. Roads connecting the construction site with the quarry and the harbor had to be surveyed, staked out, and graded. Stone was gathered to surface the roads where the existing ground was soft sand. At higher elevations, the road was traversed by bedrock limestone. Where heavy traffic was expected, the Egyptians cut paving stones and placed them on the roadway. To level out some road routes evidently required the excavation, transport, and then placement of an estimated 20,000 cubic meters of rock and soil.

Then there was the question of temporary housing at first and then later its expansion into a permanent worker's village to house the core group of supervisors, stonemasons, artisans, and skilled tradesmen responsible for the construction program. Author Craig Smith describes these in considerable detail based on archaeological research done at similar sites elsewhere.

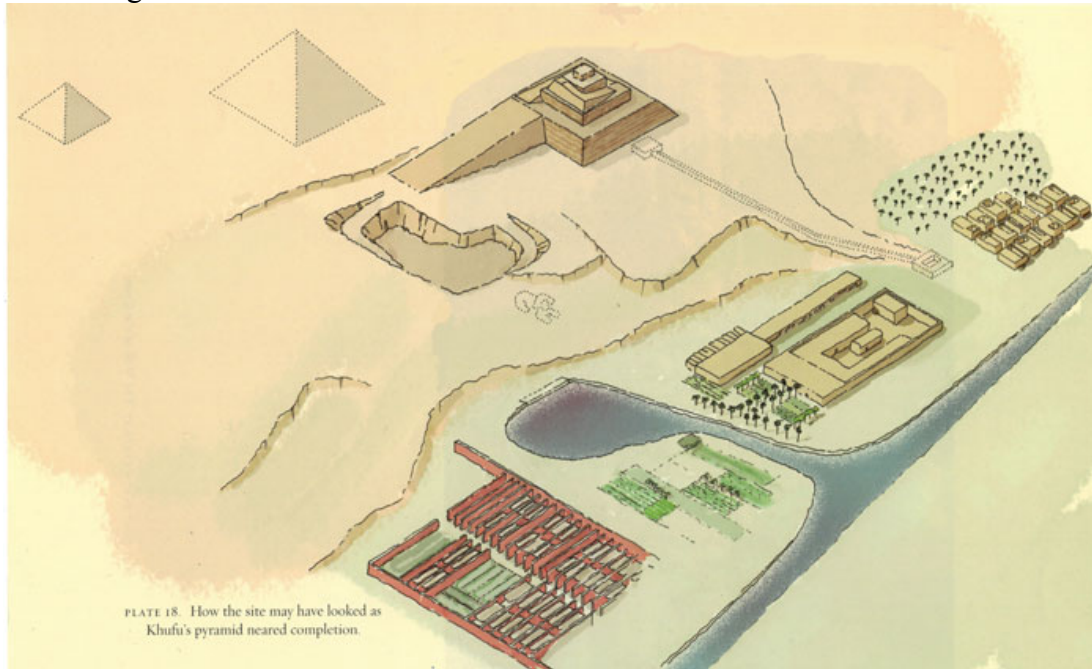


Figure 5: Conceptual site construction layout nearing pyramid completion¹⁹

Craig suggests that if we were now able to visit Giza back in 2547 BC, we would see the construction site swarming with thousands of workers, so many in fact that they would populate a small city. They would be a confident and proud people with good reason – they were engaged in an unprecedented construction project, and were executing it masterfully. In fact, with their own hands, they were building

a structural colossus. It was a colossus challenge that would endure for millennia, as one of humankind's most brilliant achievements. Hemiunu's orchestration of the work was superb.²⁰

Obviously, we were not able to visit Giza that long ago, but we did have an opportunity to visit the site in recent times. The picture shows Max Wideman riding a recalcitrant camel at the foot of the Great Pyramid on a sizzling hot day taken with an obsolete camera.



Figure 6: Max Wideman on a camel at Giza

In subsequent chapters, Craig goes on to discuss the concept of the Great Pyramid's design, including the presence of internal chambers and access tunnels, the use of the available materials, and how the large lintel beams were moved and placed. He also postulates the size and organization of the workforce by digging down to details such as how much dirt can an individual worker carry in one of those wicker baskets.

Based on his assessments, Craig then prepared a critical path schedule for the construction of the pyramid by subdividing the work into eighty activities, divided into fifteen major categories. As a point of interest, he used Primavera Project lanner (usually referred to as "P3") to perform his analysis.²¹

Craig concludes with these observations:²²

"Although we are uncertain of just how the Egyptians built the Great Pyramid, it continues to stand today, awesome testimony to the skill and sheer determination of the ancient race who built it. We must also stand in awe of their program management techniques. They must have had highly developed administrative and planning expertise.

That's because the complexity and logistical requirements of the pyramid project are so great that it would not be possible for a single individual, or even an uncoordinated group of individuals, to carry out such an undertaking. The fact that the Egyptians could plan, organize, and execute an undertaking so complex, with the marshaling of so much labor²³ points to their remarkable skills in managing the work.

Their **program management** was an accomplishment no less impressive than the legacy of stonemasonry that they left behind."

With this in mind, it is worth noting that in Appendix 4 of the book, Craig Smith includes a complete *Primer on Program Management* — another good reason for buying the book.

R. Max Wideman
Fellow, PMI

¹ Regarding copyright: Unfortunately we were unable to contact either the author or the book's publisher. However, the copyright statement on p4 does permit extracting quotations for purposes of reviewing this book.

² Author's Note, p10

³ Ibid, p11

⁴ Whether they are called "large projects", or more correctly "capital programs".

⁵ Personal collection.

⁶ *How the Great Pyramid was built*, p16

⁷ Ibid, p17

⁸ Ibid, p19

⁹ Ibid, p23

¹⁰ See Chapter 8, p202

¹¹ Ibid, p44

¹² Ibid

¹³ Ibid, p73

¹⁴ Ibid, p74

¹⁵ Ibid, p82

¹⁶ Ibid, p83

¹⁷ Ibid, p84

¹⁸ Ibid, pp84-5

¹⁹ Ibid, Plate 18 opposite page 97

²⁰ Ibid, p150

²¹ Ibid, p226. Samples of the schedule printout are included in the book.

²² Ibid, p233.

²³ Indeed, the labor force engaged a significant fraction of their population at the time!