

By Ken Y. Luo

ROAD TO THE "SKY DOME"

Unveiling the Secrets Behind the Façade System
of the China National Grand Theatre

罗忆 著

“天穹”之路

解密国家大剧院屋面工程



清华大学出版社

本书以作者亲历的国家大剧院穹顶工程为背景,展现了从构思、设计、试验到组织指挥建设的完整历程。书中故事生动曲折,倾诉言真意切、激情澎湃,感人至深,宛如报告文学;所涉及的技术举世瞩目,体现了作者学贯中西的才识,并且图文并茂,双语映照,仿佛专业画廊。本书把国家兴旺与个人事业发展、人文与技术、美学与建筑三者结合得浑然一体,当属难得一见之作。

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北京



作者：罗忆

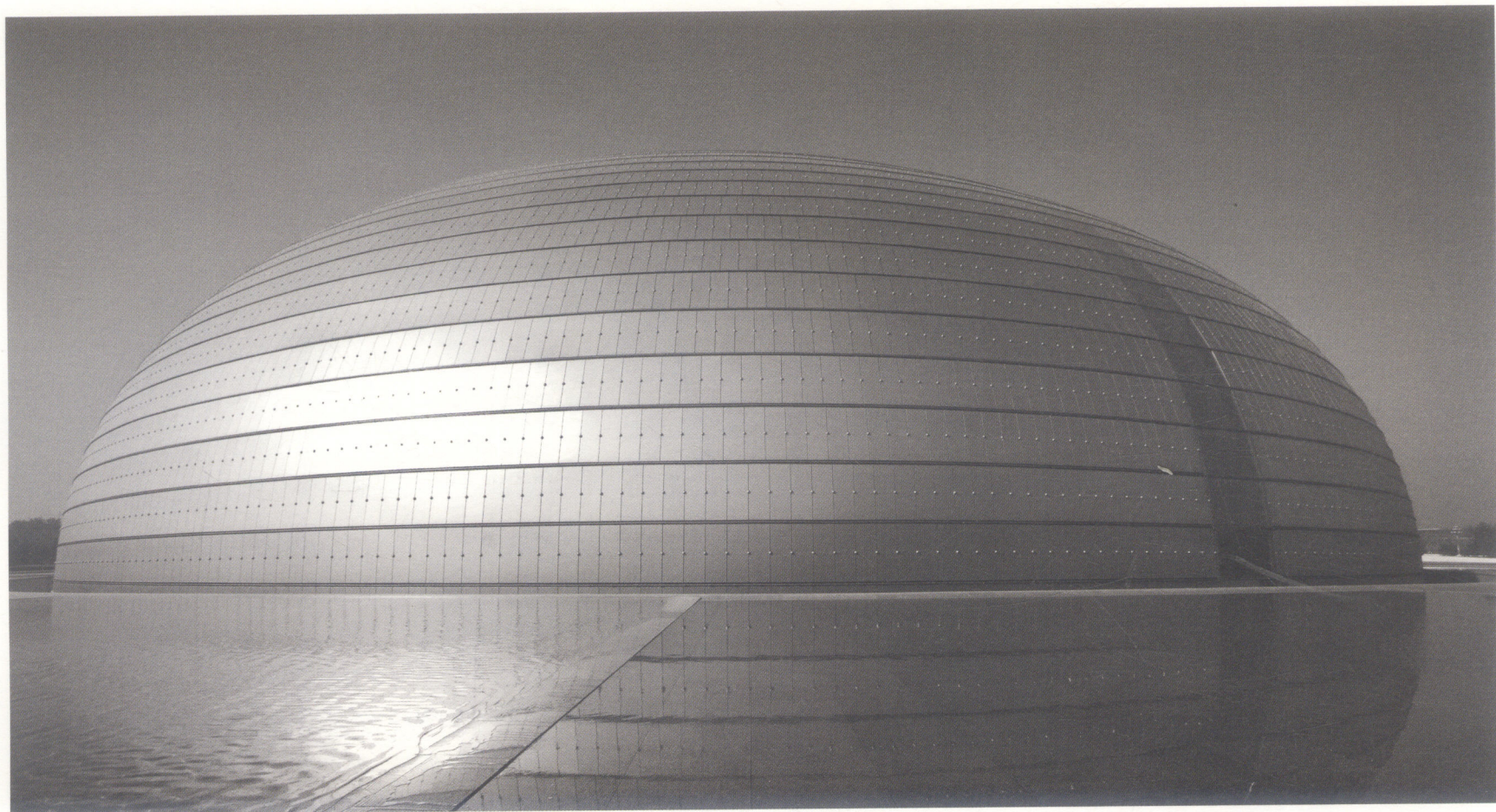
Author: Ken Y. Luo

罗忆，男，广东顺德人，中国建筑学会理事；英国皇家特许建造师；清华大学建筑玻璃与金属结构研究所学术委员会副主任；中国建筑金属结构协会幕墙委员会专家组成员；建设部幕墙门窗标准化技术委员会专家组成员。

罗忆先后在中国、美国、澳洲求学，获硕士学位，曾在欧洲和美国从事玻璃工程研习。1994年开始从国外引进先进的工程技术并创新应用，极力推动生态节能建筑工程技术的发展，主持完成了多个城市的标志性重点工程的深化设计和施工。被评为“2004全国十大建设科技人物”之一。获北京市科学技术二等奖、广东省科学技术二等奖、珠海市科学技术一等奖。著有《建筑幕墙设计与施工》、《建筑节能技术与应用》、《玻璃幕墙设计与施工》、《建筑玻璃生产与应用》、《建筑玻璃应用技术》、《玻璃·建筑·艺术》、《建筑装饰玻璃与艺术》等专著。获相关技术专利五十多项。

Ken Y. Luo, male, born in Shunde, Guangdong, Commissioner of the China Association of Architecture; member of the Chartered Institute of Building; Deputy Director of the Academic Committee of Architectural Glass and Metal Structure of Tsinghua University; member of the Expert Team of the China Association of Architectural Metal Structure; member of the Expert Team of the Technological Standardization Committee for Curtain Walls, Doors and Windows affiliated with Ministry of Construction.

Mr. Luo has been educated in China, USA and Australia, has acquired a master degree, and used to work in glass engineering in Europe and USA. In 1994, Mr. Luo introduced foreign advanced point-fixed glass technology to China, propelling the rapid development of the ecological construction technology and point-supported glass industry in China. Awarded: one of the "2004 China Top 10 Figures of Architectural Technology," second prize in the Beijing Science and Technology Award, second prize in the Guangzhou Science and Technology Award, grand prize in the Zhuhai Science and Technology Award. Written: ***Design and Installation of Architectural Curtain Walls; Architectural Energy Conservation Techniques and Applications; Design and Construction of Glass Curtain Walls; Production and Application of Architectural Glass; Glass Curtain Wall Application Techniques; Glass, Architecture, and Art; Architecture Decorative Glass and Art.*** Obtained over fifty technological patents.



|| 序 ||

建筑是社会文明进步的真实写照，建筑发展的历史路径和不同时期优秀的代表性建筑，印证了一位西方建筑史学家对建筑意义的阐述：建筑的意义几乎囊括了人类所关注事物的全部，若要确切地描述其发展过程，就等于是书写整个文化本身的历史。我理解，这里的文化是广义的，不仅是美学层面，还包括材料与技术。以中国为中心的东方建筑，是以木质材料结构为特征，而西方建筑则以石头为基本材料，结果都创造出美轮美奂的建筑形态。随着建筑技术的进步和新型材料的应用，建筑形式和艺术风格也在发生着相应的变化。

改革开放30年来，中国城镇化快速推进，建筑业也有了长足的发展。无论是勘察设计还是施工建造，各个方面都取得了令人称道的成绩。建筑市场的开放，为我们与世界先进的设计、施工同行的交流与合作提供了历史机遇。中国工程技术人员在建设过程中表现出高超的能力与水平，在与国外同行的竞争中取得进步并得以发展，他们学习国外的先进技术和经验，发扬自己的优良传统，施展自身的聪明才智，在竞争中发展自己、壮大自己，使自己走向成熟。

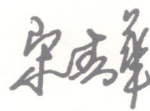
罗忆和他的团队用行动给我们做出了很好的榜样。经过近十年的发展，他们从无到有，从小到大，从国内到海外，一步一个脚印，在日益激烈的市场竞争中完成了一个又一个赏心悦目的工程。中国国家大剧院是举世瞩目的重大工程，在建设过程中，他们凭借中国人特有的毅力与精神，充分发挥自己的创造性，克服了许多从未遇到的困难，创造了一批新技术、新专利，完成了国家大剧院屋面系统的建设。他们完善了原有设计的同时，为国家也节省了资金，创造出了令人欣喜的奇迹，博得了业内人士的赞赏。国家大剧院屋面系统充分体现了中国人的智慧和理想，成为中国工程技术人员与国际大师和谐合作的典范。

除国家大剧院之外，罗忆和他的团队还先后参与建造了多个极具挑战的项目，如法国著名建筑师让·努维尔设计的美国第十一大道100号以及卡塔尔多哈高层办公楼，加拿大著名建筑师卡洛斯设计的杭州大剧院，法国ARPE设计的上海火车南站，日本著名建筑师矶崎新设计的中央美术学院美术馆、仙田满设计的上海旗忠网球馆，英国著名建筑师哈迪德设计的广

州歌剧院，美国SOM设计的北京联想融科大厦，德国欧博迈亚公司设计的中关村巨型光盘，澳大利亚考克斯集团设计的南京奥体中心。同时，也完成了一批中国建筑设计大师的作品，如北京市建筑设计研究院张宇设计的北京植物园展览温室，清华大学建筑设计研究院设计的故宫博物院午门展厅改建，中国建筑东北设计研究院设计的深圳机场，中国民航机场设计院设计的呼和浩特白塔机场，上海同济大学建筑设计研究院设计的上海汽车博物馆等，这些项目也都获得了多方的好评。

1999年，罗忆提议组建了清华大学建筑玻璃与金属结构研究所，多年来不遗余力地进行学术研究，促进了我国建筑新技术的开发和创新应用，同时获得了大量的专利技术和各种奖励，相信他们的研究成果，一定会为我国建筑设计的创新，提供新的技术支持，为繁荣我国的建筑创作，做出积极的贡献。

祝愿罗忆和他的伙伴将智慧化作源源不断的事业生机，以经验成就更多的建筑大师，创造出更新更美的建筑形式，用社会给予的回报开拓更高更广阔的世界建筑技术新天地。



中国建筑学会理事长
原建设部副部长

|| Foreword ||

Chunhua Song

President of ASC

Former Vice Minister of Construction of China



Architecture provides a genuine reflection of social and cultural progress. From the historic path of the architectural development and the distinguished representative works built in different times we could see the significance of architecture just as a western architectural historian enunciated. In his view, architecture embraces all aspects that human beings are concerned about so to describe its development is equal to write the history of the whole culture. As I understand, the culture referred to here is in a broad sense that it contains not only the aesthetical aspect but also the aspects of materials and technology. The oriental buildings as represented by Chinese buildings are characterized by wooden structure while the western have stone as the basic material. Both create gorgeous architectural forms. With the development of building technologies and the application of new materials, architectural forms and styles have been changing.

Over the thirty years since the Reformation and Opening policy, China has been urbanized at speed. The building industry has grown by leaps and bounds. Remarkable achievements have been made in survey and design as well as construction. With the opening of the building market we have been offered a historical chance to exchange and cooperate with our foreign counterparts in design and construction. Our engineering technicians have displayed outstanding skills and sophistication in the course of construction and made huge progress in competitions with foreign counterparts. On one hand, they learn advanced technologies and experience from foreign countries; on the other hand, they carry

forward our good traditions and exert their own talent and intelligence to gain self-development and maturity in competitions. Ken Y. Luo and his team have proved to be role models through their actions. During almost ten years of working in and out of China, with true determination and real effort, this team emerged and grew enormously, accomplishing glamorous projects one after another. The China National Grand Theatre is a huge, monumental project that has attracted the entire world's attention. In the course of construction, they practiced creativity and overcame, with the unique Chinese spirit of persistence, many difficulties that were never encountered before. In addition to perfecting the original design, they have saved construction funds and created an ecstatic architectural miracle, receiving compliments from both in and out of the architecture industry. The façade system of the National Grand Theatre fully exhibits the talent and aspiration of the Chinese people. It has become a showpiece of harmonious collaboration between Chinese engineering technicians and world renowned architects. In addition to the National Grand Theatre, Mr. Luo and his team have been engaged in many highly challenging projects including 100 11th Avenue, New York and the Doha High-Rise Office Building, by Pritzker Award-winning French architect Jean Nouvel, the Hangzhou Grand Theatre designed by well-known Canadian architect Carlos, the Shanghai Southern Railway Station by French ARPE, the Central Institute of Fine Arts Gallery by famous Japanese architect Arata Isozaki, the Shanghai Qizhong Tennis Center by Mitsuru Senda, the Guangzhou Opera House by famous British architect Zaha Hadid, the Beijing Lenovo Building by SOM from the

United States, the Zhongguancun "Disc" by Ober-Meyer from Germany, and the Nanjing Olympic Center by COX Group from Australia. They have also completed works designed by Chinese architects including Beijing Botanical Garden Conservatory designed by Yu Zhang from Beijing Institute of Architectural Design and Research, the renovation of the Meridian Gate (Wu Men) Exhibition Hall of the Forbidden City by Architectural Design and Research Institute of Tsinghua University, Shenzhen International Airport by China Northeast Architecture Design and Research Institute, the Huhhot Baita Airport by China Civil Aviation Institute of Architectural Design, and the Shanghai Auto Museum by Architectural Design and Research Institute of Tongji University. By accomplishing all these domestic projects, they have also received compliments from all rounds.

In 1999, Mr. Luo proposed the establishment of the Institute of Glass and Metal Architecture of Tsinghua University, where his inexhaustible efforts for academic research over the years has promoted the development and creative application of China's new architectural technologies, obtaining a great number of patented technologies and awards. I believe their research results would provide technological support for the renovations in Chinese architectural design and contribute to the prosperity of our architectural creation.

Well wishes to Mr. Luo and his companions that they would use their wisdom to create business opportunities, use their experiences to perfect more architects' careers and create more new and beautiful architectural forms, and use their power to open up a whole new world of building technologies.



用心，一切皆有可能 自序

驻足长安街，人民大会堂西侧，一泓碧水中，卧着半边“巨蛋”；微波荡漾里，侧影淡淡晶莹，这就是中国国家大剧院——中国文化艺术的最高殿堂——金碧辉煌，令人神往。

生命中这段时光，参与建造了这座艺术殿堂。我们为之日夜奋斗，挫折无数之后，终于完成了这个历史重任！此时此刻，我心潮澎湃，思绪万千。工程中的一幕幕，让我浮想联翩……

要是当初没有尽力诉说方案的是与非；要是当初不舍弃另一些重大项目；要是当初不坚持修正方案原则；要是当初不与Viry合作；要是当初不与安德鲁顶牛或者继续顶牛……我害怕任何原因导致的其他结果。如果错过了参与这个重大工程，我定后悔一辈子！

谁也没有想到，我这个医科大学出身的“工人”，竟然登上了这远眺中南海和天安门的大剧院顶上，戴着“技术专家”的帽子，头头是道地

指东划西，居然也言听计从者众；更何况在这最重要的图纸上庄严签字，我当然明白其中的神圣与责任。

说是个政治活儿吧？是啊！它令几代人魂牵梦萦，系着无数人的情结情绪；说是个艰辛的活儿吧？当然是啦！它让人花心思、用心力做上好几年；说是个赚的活儿吧？更是啊！它使你往后的人生精神富足，因为再没有比这更美的活儿了，在梦中想起时也会笑出声来！

论及时光，在历史的长河中，在几千载人类文明历史进程中，国家大剧院可能未算几许；说到大小，从宇宙角度来衡量，国家大剧院更是微小得无以言及；念及至此，纵然也有些许悲观。当然，我们不能从时间、空间的角度来衡量我们的国家大剧院，我们更无法用言语表达它代表国家繁荣昌盛的独特社会、文化、艺术和历史价值。

一九九八年在历史博物馆观看大剧院方案，

如梦游戏；二零零一年接触大剧院建设之后，它像一条丝带把我们与之联为一体。不很富足的我们，心怀坦荡，用恒心和双手，靠经验和智慧，倾注全部时间、精力，放弃其他许多、许多……如此大无畏的忘我精神，令我们能在一次又一次跌倒中站起来。

有幸于大剧院工程中与保罗·安德鲁大师切磋。大师对建筑整体的宏观构想，使人赞不绝口；对工程的细心程度，更令人惊叹不已，就连一个小螺丝的拧法，一个小胶垫的摆放，无不引经据典、微细调拨，使之完美。大师之谆谆教导，历历在目；大师之虚怀若谷，集众之长，令人折服。

更有何弢、戴复东两位恩师，有教无类，指点迷津，使我们能放纵大师之原意，遵旨创作，造就无限。

用心，一切皆有可能！

罗忆 2007.12

Try: Everything is Possible Preface



施工中的国家大剧院
The Theatre under construction



雨后的国家大剧院
The Theatre after rain showers

Along Chang'an Street, west of the Great Hall of the People, floating in a reflecting pool, lies half a dome; amidst the shimmering water, with a sparkling silhouette, this is the National Grand Theatre, China's new locus for the cultural and performing arts.

This period of life, participating in the erection of this temple of the arts, we toiled day and night, overcame countless obstacles, and finally, we have fulfilled this monumental mission! At this time and place, I can no longer resist my upsurge of emotions, and thoughts run wild. Reflecting on the numerous scenes of this project, memories stream through my mind.

If we had not exhausted our efforts in arguing the validity of our proposal; if we had not given up other large projects; if we had not maintained our principles in leaving the proposal unaltered; if we had not cooperated with Viry; if we had not stood up to Andreu.... I fear to think of the possibility of any other contingency leading to any other result. If I had missed the opportunity to participate in this project, I would have regretted it for life!

No one would have thought that I, a medical school graduate, would eventually stand on top of the National Theatre, looking upon Zhongnanhai and Tiananmen Square as a "technical expert," demanding this and that and more surprisingly, actually having a complacent audience, not to mention having my signature on this most important design drawing; naturally,

I understood the sacredness and responsibility that this signature represented.

Some say this is a political job? It is! It has left generations of people yearning and dreaming; it is tied with innumerable sentiments and emotions. Some say this is a tough job? Of course it is! It forces people to devote their energy, heart and soul for many years at a time. Some say it is a profitable job? Even more so! It motivates you through life by enriching your spirit, because there is no job more perfect than this, and it puts a smile on my face whenever I dream of it!

Reflecting on time, on history, on the progress made in thousands of years of human civilization, the National Grand Theatre may not seem much; in terms of size, from a universal point of view, the Theatre may seem miniscule; and thinking in these terms may seem pessimistic. Surely, we cannot use the perspectives of time and universe to measure the value of our National Grand Theatre; we are at a lack of words to express what it means as a monument for the strength of a country, as a symbol for a unique society, culture, art and history.

The first introduction to the proposal for the Grand Theatre at the National Museum of History in 1999 seems like a distant dream; after the first exposure to the construction of the Grand Theatre in 2001, it was as if a ribbon had connected us. Plain and indistinct, depending solely on perseverance, an indomitable spirit,

and our bare hands, we poured in all our time and energy, giving up much, much more.... It was this fearless, selfless attitude that helped us stand up after every falter in step.

Fortunate to have had chances to work with renowned French architect Paul Andreu throughout the Grand Theatre project, being exposed to a master's conceptual view of architecture was enlightening; his attention to detail was astounding, from the way a small screw was to be turned to the placement of a tiny pad, he would refer to the classics and adjusted every detail for perfection; his teachings still leap before my eyes; his modesty and talent were equally remarkable.

There were also Teachers Tao He and Fudong Dai who divulged their knowledge and guided us, allowing us to give free reign to the architect's original intent and use our creativity and imagination to construct unlimited possibilities. Try, and everything is possible!



Ken Y. Luo Dec. 2007

中国国家大剧院——举世瞩目的重大工程，承载了几代中国人梦想的艺术圣殿，聚焦了世人无尽期待目光的建筑奇观，终于在历经半个世纪的风雨历程后华丽亮相。

跨度为212m的穹顶无疑是大剧院最显著的特色。复杂的钢结构主体上，富有太空气息的钛金属屋面简洁流畅，晶莹通透的玻璃幕墙熠熠生辉，两种非常质朴的材料刚柔相济，浑然天成，构筑了建筑史上富有传奇色彩的璀璨明珠。

然而，很多人并不知道，这颗明珠的筑就过程远非世人能够想像。从2002年开始做方案到2006年将最后一块保护膜从钛金属板上撕掉，展现在世人面前的是一个令人惊叹的天穹，我们已历时五年的艰辛！

法国建筑大师充满浪漫气质的设计方案在实践过程中遭遇困难重重；我们提出的屋面系统改进方案在得到肯定前穿越的障碍更是无法想像；建造施工过程中

中不断的技术改革、材料更新才使得方案更加贴近现代化的大剧院需求……凭借智慧与坚持，合作与创意，我们一路打硬仗、攻难关，完成了国家大剧院屋面系统的方案设计、深化设计、模型制作、材料加工及安全施工，将这个穹顶的蓝图变成了现实，为这个引人入胜的巨型“皇冠”成功加冕。

如今，我依然经常穿行在工地，穿着工作服，戴着安全帽，和工人们并肩作战，继续着我的“作业队长”职责，将全部的精力投身在生态建筑系统的研究、开发与应用之中。

2007年的12月22日，我应邀参加国家大剧院首演，坐在自己亲手铺就的穹顶之下，我开心地笑了，回顾在大剧院工地的两千多个日日夜夜，我感慨万千。

本书记录了这个世界第一大穹顶的筑就过程，记录我们团队日夜奋战的点点滴滴，记录我的真实心路历程。

大剧院预演成功了，和业主委员会主席万嗣铨一起登上屋顶照张相，
我们开心极了

The Grand Theatre preview was a success, going on the rooftop with
Chairman Wan, the owner committee, we were overjoyed



The National Grand Theatre is a national construction project which has attracted worldwide attention, a palace of the arts that carries with it the aspirations of generations of Chinese, and an architectural wonder that countless people are looking forward to seeing. Now, after half a century, it has finally been unveiled.

The dome, with a span of 212 meters, is undoubtedly the most distinctive feature of this grand theatre. Constructed over the complicated steel structure are shining glass curtain walls and a simple and smooth titanium façade that evokes a sense of outer space. These two plain materials are fashioned in a harmonious way and have contributed to the creation of the most legendary building, resembling a brilliant pearl in the history of architecture.

However, the process by which this pearl was built does not paint a rosy picture. From 2002, when the designing began, till 2006, when the plastic film was removed from that last titanium panel, when this stunning sky dome was presented to the world, we had spent five years of life in toil!

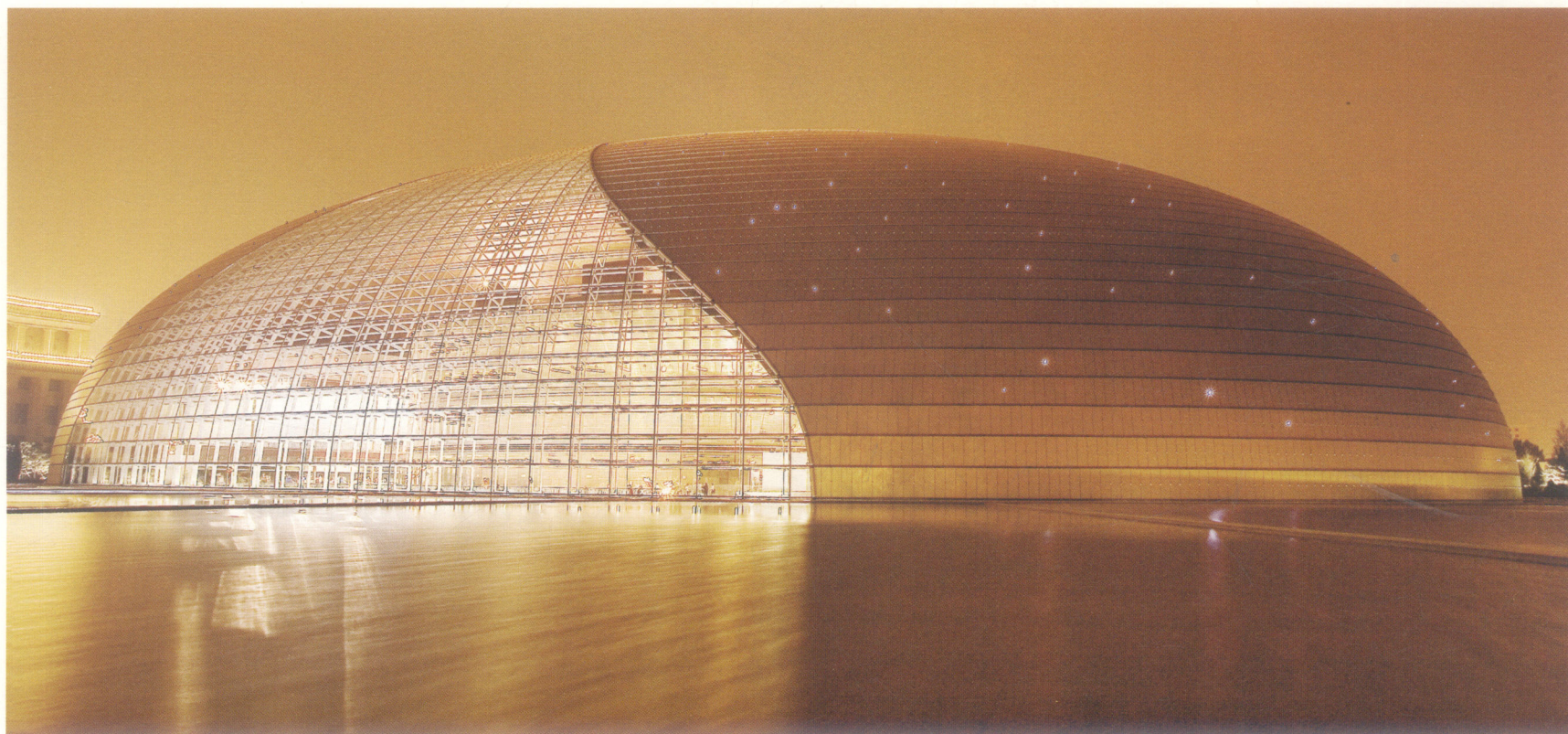
The execution of the French master's romantic design encountered numerous difficulties when put into practice; throughout construction, it was necessary to continually improve techniques and materials in order to bring the modernistic Grand Theatre to life. With pure intelligence and perseverance, cooperation and creativity, we overcame the various difficulties, completing the conceptual design for the theatre's roofing system, the detailed design, model production, material fabrication, and installation - bringing this large dome from the blueprint to reality, finally

"crowning" this exhilarating, enormous building.

Today, I still often choose to spend my time at work sites, wearing a uniform, a safety helmet, fighting side by side with my fellow workers, continuing to fulfill the responsibilities of "captain," putting effort into the research, development, and application of the ecological architectural system.

On December 22, 2007, I was invited to the premiere of the National Grand Theatre. Sitting under the arched ceiling that I constructed with my own two hands, I laughed. Reflecting upon the more than two thousand days and nights spent at the theatre work site, my feelings overflowed.

This book chronicles the construction of the world's greatest dome, reports the days and nights that my team and I fought for the its completion, records my thoughts and feelings throughout this time.





一个偶然的机会，有幸看到了大剧院的方案图纸。
一段据理力争的言论，成为了众人关注的焦点。
一扇难得的机遇之门，开启了一场精彩的技术博弈。
一个智慧的“节点”，赢得了大师的赞赏。
一个简单的工艺，解决了大穹顶的防水难题。

An accidental opportunity, luckily saw the theatre's design drawings.

A strong, rational debate, eyebrows were raised.

A rare chance, an exciting technological contest began.

A brilliant, innovative detail, the French master complimented.

A simple process, the waterproofing headache was solved.