Gold Medal address 2016
The Adventure of the Itinerant Engineer

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I had a job during the summer of 1974 in London with the engineering firm of Flint & Neill. I mailed out (not emailed, at that time, of course) some 50 résumés to firms across London. I found the names of the London firms through the copies of *The Structural Engineer* that my university in the USA had in its library. It was a difficult time economically, and Flint & Neill was the only firm to offer me a position. I enjoyed my work there over that summer, helping with an analysis of the Wye Viaduct and designing guyed masts.

On my last day at the firm, Mr Neill and Dr Flint took me to lunch at an elegant club. Towards the end of lunch they asked me why I had applied for a position in London. I replied that I had read *Sherlock Holmes* as a young man, and had become enchanted with England, Baker Street, the Baskervilles and their moors. Then, being perhaps a little too forward, I asked them why they had hired me. They looked at one another and then replied that they had read *Huckleberry Finn* when they were young!

So, in a sense, my long relationship with structural engineering practice and with the UK began with Sherlock Holmes. And, to this day, I go back and read him occasionally when I need a break from the 21st century.

As I think back on my career, I realise that Sherlock Holmes has given me more than just that summer job – in many ways, my career has been guided, for better or for worse, by how he conducted his consulting practice. His detective practice involved many of the same issues that we, as engineers, face in our work: his work required technical knowledge; he had clients of all sorts to deal with; he worked with intransigent public officials; he had to use his skills to investigate unknowns and arrive at logical conclusions; and so on.

To be fair, though, there are in fact a few small bits of wisdom that I acquired along the way that didn't come from Sherlock, but rather from colleagues and friends.

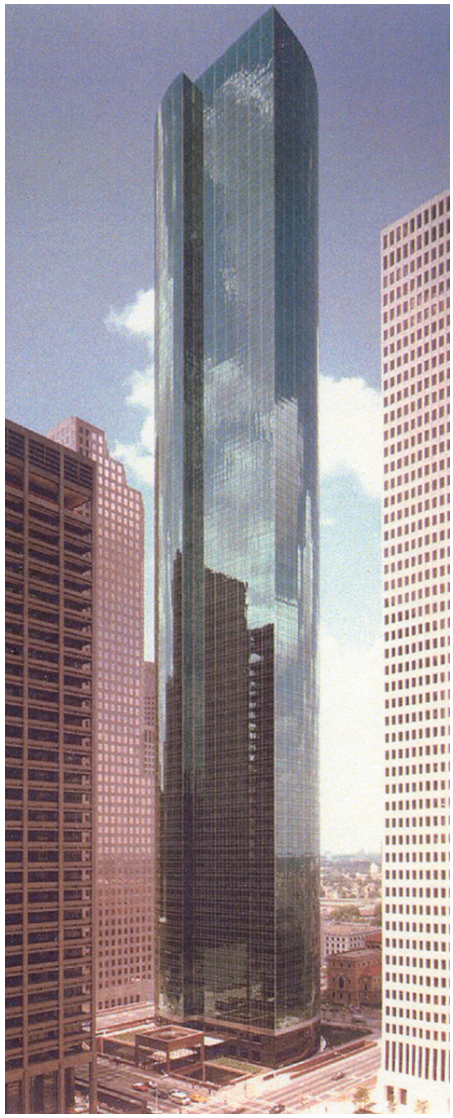

Figure 1
Allied Bank Plaza building (now Wells Fargo Plaza) in Houston, Texas

I thought, since the award – for which I am extremely honoured and sincerely thank the Institution – is for a long career, that it might be of interest to share with you some of these little bits of wisdom that others, including my good friend Sherlock, have shared with me over the years.

Critical thinking

> "It works the way you hooked it up, not the way you thought you hooked it up."
>
> Robert L. Halvorson

My father, who was an electrical engineer, was always tinkering with various projects and would often let me help him. After my projects didn't work – a frequent occurrence – he would say this to me. This simple little saying is really the essence of our work, in that we as structural engineers need to be able to understand the nature of things and predict how our designs will work. (Here, I must admit to having several pairs of electrician's pliers with two round holes burned in them from cutting live wires.)

Too often, we read about a hurricane or an earthquake that proved us wrong, or a structure that revealed an analysis that didn't reflect the way the building really behaved. We need to think critically about our work – questioning our assumptions to make sure that we have in fact considered all aspects of a situation. My dad's saying is closely related to the idea behind the quote from a forgotten military general, who said, "If the map doesn't match the ground, then the map is wrong."

Does it look right?

"Mathematics is supple and the friend of intuition."

Fazlur Khan

Fazlur Khan led the structural design of the Sears Tower and John Hancock buildings in Chicago in collaboration with Hal Iyengar, John Zils and Stan Korista, who all mentored me. In this quote, Faz was saying that, if we conceive a design that intuitively "looks right", then the subsequent analysis and design will be simple, elegant and support the design idea. He worked in the days when engineers used slide rules (as I did when I started at Skidmore Owings & Merrill in 1975). It was important at that time to develop structural concepts that could be understood, analysed and designed with simple, approximate methods.

Today, when I see young engineers jump immediately into large three-dimensional analyses of somewhat random structures with literally millions of members, I know the models are too complex for them to visualise what answers they should be getting, or where the loads should be going. That is not a comfortable place to be. (Sherlock also touches on this idea: "If you were asked to prove that two and two made four, you might find some difficulty, and yet you are quite sure of the fact." – Sherlock Holmes, *A Study in Scarlet*.)

"The great buildings of all time generally have an underlying structural logic to their form and their design that is apparent to laymen."

Anonymous

Think of buildings that people recognise as great buildings. The chances are that those buildings exhibit some sort of underlying logic based on structural principles that your mother, your neighbour or a cab driver could see and understand. The Pantheon, the Eiffel Tower, the Chrysler Building in New York, Tower Bridge, the John Hancock Center in Chicago come to mind while thinking of earlier generations of buildings. Other project designs that have a thin facade based on an architectural fad of the moment don't tend to stay relevant. There are great buildings that don't seem to fit this pattern at first glance, but in fact do. The Guggenheim Museum in Bilbao, designed by Hal Iyengar, is as randomly shaped as buildings come, but in fact its randomness was achieved by a very logical structural module that was repeated – bent and twisted, but repeated – to create the final form of the buildings.

Biography

Robert A. Halvorson leads the structural engineering practice of Halvorson and Partners, a WSP | Parsons Brinckerhoff company. Bob, as he is known by most, is an industry leader in the structural design of high-rise buildings and long-span structures. He has collaborated with notable architects across the globe, developing clever structural systems for one-of-a-kind buildings. Over the last four decades, Bob has engineered more than 60 buildings of 40 stories or taller, including Allied Bank Plaza in Houston, 111 West Wacker in Chicago, Torre Caja Madrid in Madrid, Burj Mohammed bin Rashid Tower in Abu Dhabi, and Hanking Center in Shenzhen.

Bob's interest in structural design began with a summer job in high school as a carpenter's helper. Constructing simple wooden frames spurred a curiosity about how larger, more complex structures were designed. Through his formal studies at Cornell and Stanford Universities his curiosity escalated into a passion.

Bob began his career with Skidmore Owings & Merrill (SOM), serving in the firm's Chicago, Houston, New York and London offices. In 1983 his demonstrated leadership and creativity earned him the distinction of becoming the firm's youngest partner at the age of 31. Bob left SOM and founded Halvorson and Partners in 1996. Within 10 years the firm had a staff of nearly 70 professionals with award-winning, prominent building designs in Madrid, Dubai, Abu Dhabi and Hanoi.

Under Bob's leadership, Halvorson and Partners merged with WSP in 2015, a strategic move that allowed his firm to service a wider range of clients in an increasingly competitive industry.

Eliminating failure

"How often have I said to you that when you have eliminated the impossible whatever remains, HOWEVER IMPROBABLE, must be the truth?"

Sherlock Holmes, *The Sign of the Four*

Holmes' approach to solving his fictional mysteries applies directly to our forensic engineering mysteries. But it also has applications in engineering design: it is important for us to distinguish between designing something new and unique, or outside our experience, and designing something which has an established design process.

With a typical beam or column design, an engineer can follow a well-trod path to an acceptable answer and be confident that the answer will work. This is because in developing the design procedure, all the possible failure modes have been identified and eliminated.

On the other hand, if there is something about the beam or column that is slightly, but sufficiently, different, then the engineer's challenge becomes eliminating ALL possible ways that the beam or column – or indeed building – can fail. That is a much, much harder proposition – witness the Kansas City Arena, the Tacoma Narrows Bridge and the box-girder bridge failures around the world that led to my summer job helping to check the Wye Viaduct at Flint & Neill.

Sometimes these slight, but significant, differences are hard to see, as Holmes notes in "A Case of Identity": "You [Watson] did not know where to look, and so you have missed all that was important. I can never bring you to realise the importance of sleeves, the suggestiveness of thumb-nails, or the great issues that may hang from a boot-lace."

"There is a strong family resemblance about misdeeds, and if you have all the details of a thousand at your finger ends, it is odd if you can't unravel the thousand and first."

Sherlock Holmes, *A Study in Scarlet*

In eliminating ALL the possible failure modes of a unique structure, as discussed above, it is important to be able to visualise the thousand ways that it can fail. Structural engineering isn't something that can be learned in four or five years at university, or even after a few further years of practice – it requires a lifetime of study to absorb even a tiny fraction of the accumulated experience of the profession. That sort of study is a bit like "The Knowledge", the exhaustive study that prospective cab drivers go through to know the streets of London – except that, in our engineering version, our friends the architects, the researchers and the building code writers are continually shifting the streets around!

Holistic understanding

"Holmes is a little too scientific for my tastes – it approaches to cold-bloodedness. I could imagine his giving a friend a little pinch of the latest vegetable alkaloid, not out of malevolence, you understand, but simply out of a spirit of inquiry in order to have an accurate idea of the effects. To do him justice, I think that he would take it himself with the same readiness. He appears to have a passion for definite and exact knowledge."

"Young" Stamford, about Sherlock Holmes, *A Study in Scarlet*

There are great divides in our engineering practice between the theoretical and the practical, and between our understanding of the behaviour of individual structural elements and the completed whole. We have a lot of knowledge and test data about individual elements – things of a size that can fit into testing machines – but a lot less knowledge about the behaviour of entire structures. If we are to learn about those thousand "misdeeds" mentioned earlier, we need to be implementing measurements of completed buildings and bridges to see if we, indeed, do know how to extrapolate from individual pieces to collections of pieces.

Many years ago I made some unique measurements of the response of the Allied Bank Plaza building (Figure 1) in Houston, Texas (now the Wells Fargo Plaza building) during a hurricane. There have been some tremendous achievements more recently using far more sophisticated equipment – the monitoring of several buildings in Chicago, and the work done on the Burj Khalifa in Dubai are two examples, although more of the real data from those investigations needs to be published. This sort of real-world, full-scale information is of great importance to the practising engineer.

Figure 2
Russia Tower project in Moscow

"I have no data yet. It is a capital mistake to theorise before one has data. Insensibly, one begins to twist facts to suit theories, instead of theories to suit facts."

Sherlock Holmes, "A Scandal in Bohemia"

Holmes' observation has direct application to structural engineering, particularly forensic engineering. Many times while working through a challenging problem, I find my thinking changing dramatically as previously unknown facts come to light. In developing theories – as in developing structural designs – it is important to let the facts lead to the conclusions and not the other way around.

Our profession is profoundly different from others. Politicians can freely interpret "facts" to fit into their world view, but we engineers need to base our thoughts and actions on facts, reasoning and logic.

Holmes' words about thoroughness similarly apply to engineering: "'They say that genius is an infinite capacity for taking pains,' he remarked with a smile. 'It's a very bad definition, but it does apply to detective work.'" It is sometimes hard and tedious work, but necessary work, to investigate and develop all the facts one needs to develop a correct theory – or a successful design.

Better together

"'Look here, Watson,' he said when the cloth was cleared, 'just sit down in this chair and let me preach to you for a little. I don't know quite what to do, and I should value your advice. Light a cigar and let me expound.'"

Sherlock Holmes, "The Boscombe Valley Mystery"

Collaboration among engineers is very important. Gene Miller, who was a very experienced critical thinker working as an engineer for the steel fabricator/erector for the Allied Bank Plaza, said to me one day, "I never worry about the details that we talk about, I worry about the ones that we don't talk about." He told me this after we had spent the better part of a day together debating how to design and detail the steel connections for the project.

We started the day having entirely different ideas about how the load would flow through the connections, but ultimately we found compromises that both of us could agree to. Gene's point was simple: if we don't debate a detail, maybe we miss identifying a failure mode that one of us knows about, but the other doesn't.

As a practising engineer, I routinely wander up to colleagues' desks and ask for "reality checks" on things that I'm working on. Very often, my colleagues – in some cases young, in others experienced – will ask a "what about" or "what if" question that completely turns my thinking around. All of us have touched different parts of the elephant that is structural engineering and bring those different sensibilities to our designs. The more heads involved in a design, the more of those thousand "misdeeds", or failure modes, are considered in the final design.

"I left Holmes seated in front of the smouldering fire, and long into the watches of the night I heard the low, melancholy wailings of his violin, and knew that he was still pondering over the strange problem which he had set himself to unravel."

Sherlock Holmes,
A Study in Scarlet

Maybe some engineers can think up creative ideas in the middle of a busy meeting, or while driving or taking a shower. I can't. My best ideas don't come easily. Most have come after many hours of scribbling on tracing paper, often late at night after my son, Bobby, was asleep. A late-night idea for the sloped columns of the structure for the Russia Tower project in Moscow (Figure 2) became the signature detail of the architectural concept (after some improvements by Michael Gentz and his colleagues at Foster + Partners!).

NIGEL YOUNG / FOSTER + PARTNERS

Figure 3
Central Market project (now World Trade Center) in Abu Dhabi

"The design process – when it works well – is a series of logical decisions undertaken with talented colleagues leading one to an unexpected, but delightful, conclusion."

Neven Sidor,
Grimshaw Architects

The collaborative process with experts in other disciplines is the most enjoyable and creative part of the design process – the time when the final design is not yet formed and designers from all disciplines can toss out ideas with everyone reacting to and building on the others' ideas. Sometimes a design team winds up with a camel and not the thoroughbred horse that they were after, and has to start again, but sometimes the end result is new, unique and sublime.

In this process, to be effective, the structural engineer must be prepared to go beyond his or her sense of comfort in proposing previously proven solutions – but rather be comfortable proposing new ideas relying on his or her intuition. This was necessarily the case in our Central Market project in Abu Dhabi, now the World Trade Center (Figure 3). Working with Foster + Partners, we had only a week or so to develop and present the structural concepts to the developer. After winning the project, it took another year of hard work to confirm the initial structural concepts developed during that week.

Embracing constraints

"The most commonplace crime is often the most mysterious because it presents no new or special features from which deductions may be drawn... have already explained to you that what is out of the common is usually a guide rather than a hindrance."

Sherlock Holmes,
A Study in Scarlet

A professor at my university taught that design is not really a matter of seeking freedom, although that is what designers often say they are looking for. Design really is a search for constraints – what are the limits on the design? I believe that. The best, most elegant and most interesting buildings that I have been involved with resulted not from the designers having complete freedom – a large site, an unlimited budget, no programme and no zoning restrictions – but rather from having a seemingly impossible constraint on the design.

Some of these constraints have been external to the design process, like too small a site, or an unlikely mix of building uses, or trains running below the building, but some have been created within the design process. For example, Foster + Partners set out on our Torre Repsol building (now Torre Cepsa) in Madrid (Figure 4) with the idea that only the tower cores should touch the ground in order to open up the lobby to the plaza. On our Hanking Center Tower in Shenzhen with Morphosis (Figure 5), the architectural concept separated the office space from the core with a gap the full height of the tower.

These sorts of constraints on the design may be challenging, but they create opportunities for unique and wonderful buildings.

However, the unique nature of our buildings creates a difficult situation for us engineers. Many years ago, I heard a presentation by the man responsible for the computerised "BIM" system used by Boeing in the design of what was then the new 747 aircraft. The remarkable presentation opened my eyes to the differences between building design and that of many other fields of engineering.

The 747 design team had a budget for the design of a billion or more dollars and a schedule measured in years. Each and every minute piece of the airplane was the subject of rigorous design. The designers had the luxury of facilities to build and test prototypes of pieces of the airplane, and if their design failed, they could try again and again until they succeeded. Then, once the design was finalised, Boeing could sell thousands of the airplanes with an enormous income stream to amortise the design costs.

Contrast that to our profession where we have to design one, often very unique, structure within a fast-track schedule, with many design changes along the way, with a limited (even competitive!) design budget, and the design has to be right the first time. We are allowed no "do overs".

It struck me that, given the disadvantages inherent in our current structural design practices, we do a pretty good job. However, we should remember that the failure rate for the 747 is, I imagine, much, much lower than for our building structures.

Figure 4 Torre Repsol building (now Torre Cepsa) in Madrid

Making one's mark

"There are no crimes and no criminals these days... There is no crime to detect, or, at most, some bungling villainy with a motive so transparent that even a Scotland Yard official can see through it."

Sherlock Holmes, *A Study in Scarlet*

"What is the use of having powers, doctor, when one has no field upon which to exert them?"

Sherlock Holmes, *The Sign of the Four*

Unfortunately, to practice at a high level requires having clients who are interested in developing projects with unique designs, and being in a position of responsibility for the structural design. These things don't happen by chance, but require many years of learning, developing trusted contacts, developing a group of satisfied clients, and working one's way into a position of trust and responsibility.

These days, though, there is a worrying trend in the profession towards marketing and puffery and competition reflected in this quote from Sherlock describing Inspectors Gregson and Lestrade: "'What you do in this world is of no consequence,' returned my companion bitterly. 'The question is, what can you make people believe that you have done.'" I suppose I am rightly considered an old guy now, but the new world of Twitter worries me.

Resisting commodification

"It's a very sobering feeling to be up in space and realize that one's safety factor was determined by the lowest bidder on a government contract."

Alan Shepard

The astronaut Alan Shepard made this observation when the heat shield on his space capsule was thought to have shifted, creating the possibility that his capsule would not survive re-entry into the earth's atmosphere.

When I graduated from college, the Code of Ethics of the American Society of Civil Engineers prohibited engineers from submitting priced proposals in competition with other engineers. These days, it has become routine for engineers literally to bid on projects. This is truly an awful development for the profession and for society at large. Would you feel comfortable knowing that your doctor had to scheme to minimise the amount of time they spent planning or performing your surgery? The idea that, to be successful, we engineers need to think up ways to shortcut our design efforts, put less experienced personnel on projects to save fees, or jump

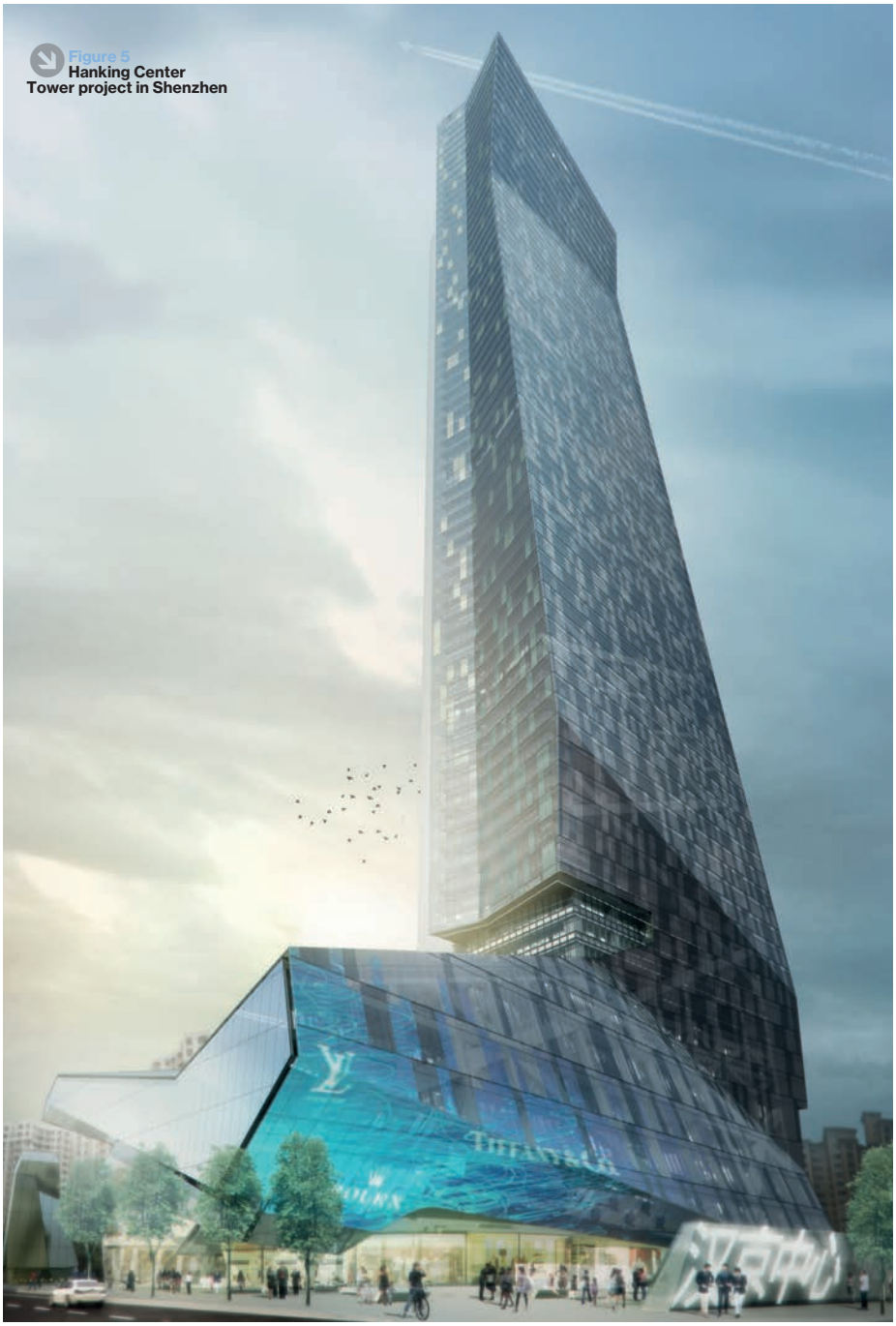

Figure 5
Hanking Center Tower project in Shenzhen

to the "standard solution" without study of creative new alternatives is a travesty.

Given where we are today, I don't know how we can ever return to being a true profession instead of a commodity, but we should all try. I feel much more comfortable with the "unworldly" approach of Holmes as described by Watson in the "Adventure of Black Peter": "So unworldly was [Holmes] – or so capricious – that he frequently refused his help to the powerful and wealthy where the problem made no appeal to his sympathies, while he would devote weeks of most intense application to the affair of some humble client whose case presented those strange and dramatic qualities which appealed to his imagination and challenged his ingenuity."

Conclusions

In conclusion, I should note that Holmes did have it seriously wrong in one area of his practice, as evidenced by the following quotes:

> Watch a recording of Robert Halvorson's Gold Medal address at www.istructe.org/resources-centre/webinars.

> "'It is of the first importance,' he said, 'not to allow your judgement to be biased by personal qualities. A client to me is a mere unit, – a factor in the problem.'"
>
> Sherlock Holmes, *The Sign of the Four*

> "But love is an emotional thing, and whatever is emotional is opposed to that true cold reason which I place above all things. I should never marry myself, lest I bias my judgment."
>
> Sherlock Holmes, *The Sign of the Four*

> "Detection is, or ought to be, an exact science, and should be treated in the same cold and unemotional manner. You [Watson] have attempted to tinge it with romanticism, which produces much the same effect as if you worked a love-story or an elopement into the fifth proposition of Euclid."
>
> Sherlock Holmes, *The Sign of the Four*

In my career, while the projects were fun and exciting, and it is greatly enjoyable to look back upon them, my most enduring memories are of people – clients, colleagues and family – with whom I worked and who helped me along my journey. These people and I shared aspirations for our projects, earnestness in our pursuits, humour in difficult times, joy in finding an elegant solution, and many other emotions – these are the things that stand out from the day-to-day work. Without Dr Flint and Mr Neill, Hal Iyengar, Stan Korista, John Zils, John Harris, Jim Swanson, Greg Lakota, my wife Melanie, my son Bobby, and many others including, of course, Sherlock Holmes, the last 40 years would not have the same meaning to me.

I thank the Institution again very sincerely for this wonderful award.