DESIGNING FOR HUMAN RELIABILITY

Human Factors Engineering in the Oil, Gas, and Process Industries

Ronald W. McLeod

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by

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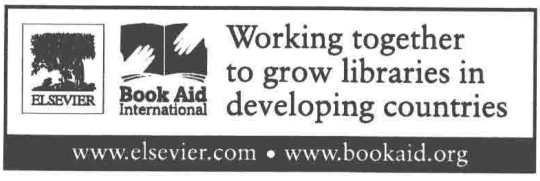

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Dedication

For Harrie.
And with thanks to Geert.
Two giants.

Preface

Being clear about your target audience is one of the first principles of human factors engineering (HFE). So, it seems a good place to start.

In 1981, I started work as a research assistant under Professor Mike Griffin in the Human Factors Research Unit, part of the Institute of Sound and Vibration Research at the University of Southampton. I worked part-time on my PhD while conducting a series of experiments funded by the Royal Aircraft Establishment at Farnborough in England. My project studied how low-frequency (0.5-5 Hz) whole-body vibration along the vertical axis (i.e., through the seat to the head of a seated person) affected the ability to perform certain manual and mental tasks. It was a small part of a bigger program aimed at understanding how environmental stressors can affect aircrews in high-performance aircraft.

In the summer of 1986, I completed my PhD and moved to Glasgow to join a medium-sized company of naval architects called YARD (now merged and diverged into various larger companies). I was to work as a human factors specialist and applied psychologist in a small team of applied scientists in the Systems Research and Artificial Intelligence Group (SRAIG).

The summer of 1986 was a period of major change for me. In addition to completing my PhD and moving to a new job, I was in the process of selling a house and moving to a new city. I can recall reading a statistic that at least two of those life events were highly correlated with suicide. Fortunately, I was young and resilient, and able to take it all in my stride. Twenty-eight years later I am still living in Glasgow, happily married and with two grown sons.

Professionally, I quickly settled into my new life. However, while Glasgow and the West of Scotland had, and has, a long and proud history of ship building, engineering and technology, times were changing. YARD was an established and well-respected firm, but little of its business—certainly little of SRAIG's business—was in Scotland. And so began my life on the road.

Since 1986, although I have lived in Glasgow, and, until I joined Shell in 2007, ran my own consultancy business in the city, most of my work has been conducted elsewhere. Until about 2003, "elsewhere" usually meant elsewhere in the United Kingdom. Since 2003, it has meant many other countries. So, all of my professional life has been spent traveling. I have never worked out exactly what proportion of my time I've spent away from home, but I estimate it is probably between 25% and 40% of the working year on average. That meant a lot of evenings eating on my own. Which brings me to *The Economist*, my regular dinner date for the past 10 or so years. I get it delivered each week (or nowadays downloaded onto my iPad), and it goes with me everywhere. I have a high regard for the journalists who write for *The Economist*. In addition to being well informed, they write supremely well

and manage to deliver a great deal of information clearly and succinctly. And I love their subtle humor.

One evening, while reading my *Economist* over dinner I read two articles that made me reflect not only on why I wanted to write this book, but also who I wanted to write it for.

In the "Technology Quarterly" section, there was an article on asteroid mining. It was about two start-up companies that intended to build asteroid-hunting spacecraft with the intention, eventually, of extracting minerals from asteroids in space. (From the perspective of 2014, this seems a somewhat fanciful notion—as the article concluded: "Asteroid mining seems likely to stay in the realm of science fiction for the time being." Time will tell.)

What really caught my attention was this description of one of the company's business models: "The idea is to build FireFly on the cheap, foregoing extensive testing and using commercial off-the-shelf components rather than custom-built electronics." "forgoing extensive testing"! My neural alarm bells were engaged. The article went on to explain, "To reduce costs further, the FireFly probes will fly alongside larger payloads on the scheduled launches."

So the idea was to get into space on the cheap by "forgoing expensive testing" and relying on other companies. Companies who, presumably, would have invested the money necessary to thoroughly test their designs in order to ensure they would actually have a reasonable chance of getting FireFly into space. And why were they avoiding the testing? In order to make the company attractive to investors by cutting what were seen as unnecessary overheads, such as testing. I wondered which business partners would be prepared to put their own venture at risk by partnering with a company willing to reduce its costs by adopting a business model based on not testing its products.

The article brought to mind other stories I'd heard of similar thinking that had led to disastrous consequences, such as an oil executive who apparently gave a speech about how costs had been reduced on the design and construction of a new offshore production platform. The company had apparently:

> *. . . established new global benchmarks for the generation of exceptional shareholder wealth through an aggressive and innovative programme of cost cutting on its production facility. Conventional constraints have been successfully challenged and replaced with new paradigms appropriate to the globalized corporate market place. Through an integrated network of facilitated workshops, the project successfully rejected the constricting and negative influences of prescriptive engineering, onerous quality requirements and outdated concepts of inspection and quality control. Elimination of these unnecessary strait jackets has empowered the projects suppliers and contractors to impose highly economical solutions with the win-win bonus of enhanced profitability margins for themselves. The. . .platform shows the shape of things to come in unregulated global market economy of the 21st Century.*

I first came across that speech on an internet site, overlaid on a series of photographs taken as the platform, the largest semi-submersible oil platform in the world at the time, sank into the sea, losing the entire $350 million investment.[1]

[1] I have not been able to verify the accuracy or attribution of this quotation, but it is has been circulating on the internet for some years.

I also had a memory of a meeting in the Chief Naval Architects office of a shipbuilder on the Clyde. He told me how they had won a contract to build military ships that were going to be designed to commercial standards. He seemed proud that their ships were intended to be sent into war zones without the blast proofing that is (or was then) normal practice for such ships. I don't know how that story ended, but it seemed to me quite a risk to accept for a short-term cost saving.

I pondered for a while and then continued my meal, returning to the contents list to see what else caught my eye. Page 68: "Google—Don't be ugly." The article explained why investors were rushing to get their hands on Google stock. A key reason was because "its Android mobile operating system is winning millions of new customers." Why? "...because its design has become much slicker."

In typical, concise *Economist* style, the article concluded:

> *... the fact remains that Google is getting better at design faster than Apple is mastering the kind of web services that have made its rival so successful. And the stock market has noticed.*

"And the stock market has noticed." There it is. The stock market. Investors. So, in the case of Google, investors had noticed that good design—more precisely, good design for the user—is a good investment. While the asteroid mining company wanted to attract investors by "forgoing expensive testing," which was seen as an unnecessary overhead, not worthy of investment.

There is something not right here. Why do asteroid mining investors not get it that testing and design go hand-in-hand? They are part and parcel of the same thing. You don't get world-class products or performance if you don't invest in both. Look at Apple. Or Dyson.

So who is this book for? My main target readers are the executives, engineering managers, project managers and others who make decisions and trade-offs about what activities to carry out and what to spend money on in carrying out their capital projects. I also hope the technical content will be of value to the designers, engineers and operations people who actually deliver projects.

Though the book is really for investors in the oil and gas and other safety-critical process-based industries— people who put money at risk in the hope of generating a satisfactory financial return. In the greatest part of the private market—at least the part that executive-level decision makers take most seriously—that means the professional fund managers and other financial professionals who constitute "the market." The individuals who control seriously large sums of capital and can apply significant pressure to the boards of private companies. Often, they are the executives of oil and gas companies themselves; because of the huge amounts of capital involved, many operations are joint ventures, either between private companies or between private companies and national governments (or the national oil companies they set up to manage their natural assets).

The book is also for the financial press and the insurance industry. The journalists whose role in international capital is to investigate, monitor and report on the activities and performance of the sector. And the insurance companies who underwrite risk in the industry, for whom incidents involving major damage to assets, environmental

damage and/or personal injury can represent significant loss. The book contains many stories and examples illustrating how the failure to achieve a reasonable standard of HFE in design can be a significant contributor to incidents. Similar lessons have been learned from investigations into numerous incidents stretching back over many years. Given the damage to shareholder return that can be involved, I find it surprising that the investors who own the companies, and the financial journalists who investigate and report on them, have not been more insistent that these lessons are learned and that action is taken to properly implement them. In fact, I find it remarkable that neither the financial press nor the insurance industry has yet shown a greater interest in the arguments I set out in this book.

I hope to raise awareness among investors about what I argue is a source of a significant loss of return on their investments. By doing so, I hope that business leaders will, at shareholder insistence, pay more attention to the ensuring that the principles of HFE are adequately applied to the design and operation of their assets. And, while the underlying theme of the book is the improvement of financial returns on shareholder investments, improved application of HFE will also lead to significant improvements in safety, health and environmental performance across the industry. The impact of human factors on health and safety has been recognized and understood for many years. What has not been adequately recognized, and has not yet been given the attention and resources it deserves, is the critical role that engineering design plays in encouraging safe behavior and avoiding unintentional human errors at the work site.

The book is not written for the academic community, although I hope that applied researchers might find some of it to be of interest. I have tried to ensure the book is grounded in good science, but I have also taken the view that, on balance, it is more important to present the lessons gained from experience along with the evidence, insights and findings available from incident investigations. Perhaps the many examples and applied experience described in the book will encourage more opportunities for improved communication between scientists and researchers on the one hand, and engineering and operational communities on the other. If the material is presented in the right way, there is a great deal that this latter community can gain by making better use of the knowledge and insights available in the academic worlds of applied psychology, human factors and ergonomics.

In summary, the book is likely to be of most valuable to the managers, engineers, designers and operations people who actually work on and deliver capital projects across the industries. Though it is really for the investors and their representatives who make decisions about how money is invested in technology-based enterprises.

Why is this news?

I am essentially an applied scientist: my background and main professional interests lie at the interface between psychology and engineering. And, as with most people who become involved in the discipline of human factors, I am passionate about what I do: I

really believe that applying the knowledge and techniques from HFE is a good thing. It's good for investors and it's good for society at large. In his 2004 book *The Human Factor* [1], Kim Vicente, a highly regarded Canadian academic, draws on many compelling stories and incidents that illustrate the impact of human factors on society. HFE is an especially good thing for the front-line workers around the world for whom the risk of injury or worse can be significantly reduced when proper consideration is given to human factors in design.

Oil and gas companies are among the largest corporations in the world. Even outside the global "majors," their leaders run challenging operations—commercially, financially, technically, legally, politically and culturally. These are intelligent, experienced and capable people with decades of experience in their businesses. And they are nearly always well informed, supported by well-resourced organizations with access to vast quantities of real-time operational and financial data.

So, why has an applied scientist written a book arguing that these same business leaders and the companies they run are missing something that is directly impacting their most fundamental objective: to deliver the best return they can to their investors? There are at least three reasons:

- Industry is not good at investigating the human contribution to incidents —whether affecting health, safety, the environment or production. As a result, industry has not generally recognized the contribution that design-induced human error makes to loss of production.
- Although, in a general sense, human factors are now widely recognized across the industry as a significant risk to industrial safety (both personal and process safety), the industry has largely focused its attention and energies on leadership, safety culture and behavior-based solutions. The general opinion of industry leaders has been that human reliability will be improved—and errors, mistakes and unsafe acts will be prevented—if the workforce can just be encouraged, or forced, to behave safely and to stop behaving unsafely. There is clearly a great deal of value in this approach, as many safety leadership and behavior-based safety initiatives have demonstrated across many industries around the world. Yet, there has been a lack of appreciation of the extent to which the behavior of people at the operational sharp-end is shaped, or facilitated, by the design of the physical and the organizational world they work in. That is the central argument of this book.
- By definition, new capital projects involve putting shareholder money at risk in the hope of generating future returns. Because capital needs to be put at risk, the pressures to complete projects as quickly as possible, risking as little capital as possible, are always significant. So anything not considered essential, or which must be paid for up front out of investors capital, inevitably comes under extreme scrutiny. Unfortunately, much of HFE often falls into that category of things that are not considered essential in project engineering.[2]

Human beings have physical, psychological and social needs and limitations that influence their approach to the work they do, as well as how safely they perform that work. These needs and limitations must be taken into account and reflected in how workplaces are designed and laid out. This concept can be foreign to senior leaders, however; it is not usually encountered as a part of the education or experience that got

[2]Shell is one of the few exceptions being the only oil and gas major to have adopted a mandatory global requirement across the entire group that the principles of HFE are to be applied on its capital projects.

them into a position of leadership. Yet, these needs and limitations make significant contributions to incidents resulting in worker injury or death, as well as equipment and environmental damage. Such incidents mean increased cost, lost opportunity and lost return on investment.

I have set out in this book to share some of my personal experiences and to present examples of things I have seen or learned in the course of my professional career over nearly four decades. It is a personal book, written largely in the first person, though drawing on published science, incident investigation reports and other material as appropriate. It includes content from my reviewers who have, on occasion, generously supplied their own stories and examples in order to help illustrate the narrative. And it draws on things I have learned from many colleagues, including project managers, technical safety specialists and other engineers and operations personnel, as well as human factors professionals, about how to make sure the money that is invested in human factors is spent wisely. I thanked some of them in the acknowledgments, and I thank all of them here.

That being said, the book expresses my personal opinions about how and why some things go wrong and my personal suggestions about how some of these things can be improved. If these opinions do not align with the state of science, academic thinking or the view of companies, regulators, or other professionals, that is fine. They are my opinions, based on my education and my experience. Take them or leave them. I do, however, hope to persuade readers that providing adequate time, attention and resources for HFE in capital projects is a sound way to spend investors' money.

On my opinions

The book expresses many opinions, some of which may appear to be critical. What is the basis for these opinions? Am I suggesting that the industry as a whole is deliberately ignoring these issues? That it is deliberately failing to prioritize human factors issues that are important to incorporating safety and reliability in the design of facilities? Of course not. In my experience, the industry cares deeply about safety and environmental protection. Companies can sometimes go to extraordinary lengths to implement controls to mitigate risks. And, of course, it is easy to find fault with hindsight.

The opinions I express reflect what I believe is a widespread lack of awareness and understanding of the complexity of human performance and of the perceptual and psychological processes that underpin it. This lack of awareness pervades the communities that set the targets and make the big decisions that shape industry, as well as those responsible for deciding how to achieve those targets. In part, this lack of understanding reflects the gulf between the scientific and academic communities that possess deep knowledge of human performance and the psychology that drives it and the stakeholders in the industry who can benefit by accessing that knowledge and using it in decision making and engineering design. Prior to working in oil and gas, I spent many years as a human factors consultant working on projects across the maritime, defense, aviation, nuclear and rail industries. I was, and still am, surprised and

disappointed at how little research—fundamental or applied—and teaching address the human reliability issues facing the oil and gas industry. Anyone who has searched the conference proceedings and other publications of professional organizations such as the International Ergonomics Association, the Human Factors and Ergonomics Society or the Ergonomics and Human Factors Society will be aware of how relatively little human factors research has been conducted for the oil and gas industry. They will also recognize how few academics,[3] researchers or consultants have experience—or, seemingly, any interest—in these issues, as compared to defense, aviation, rail or, increasingly, medicine.

So, the opinions expressed reflect what I believe is a lack of awareness and understanding, rather than any intentional oversight, on behalf of the industry. They don't apply to the whole industry all of the time: some companies are far more advanced and sophisticated in managing human factors than others. The quality of HFE on projects and in operational management can also vary enormously, both within companies and between them. But my opinions certainly apply to some organizations some of the time. They may indeed apply to some organizations all of the time. And, if my opinions appear critical, it is only because I believe there is a large opportunity for learning and improvement. If that opportunity is taken and the learning is implemented, organizations can make a significant improvement in safety and environmental management, while improving production and return on investment.

Reference

[1] Vicente K. The human factor: revolutionising the way we live with technology. New York: Routledge; 2004.

[3]There are some notable exceptions, such as Professor Rhona Flin at Aberdeen University and Professor Andrew Hopkins of the Australian National University among others.

Acknowledgments

The seeds of this book were sown in early 2007 in an email exchange I had with the late Harrie Rensink. I was working as a consultant for Shell, delivering a human factors engineering (HFE) training course at its Port Dickson refinery in Malaysia. Harrie was in the Netherlands, undergoing treatment for cancer. We, and others, had often discussed the need for a book that could give our trainees more practical background and advice on implementing HFE on Shell's capital projects, than was available in existing books, technical standards and design guides. So we concluded we should write the book ourselves. The fruits of the ideas sown then are in your hands now. Unfortunately, Harrie passed away in the middle of that year. But I fully acknowledge the debt I owe him, not only for the concept for this book but in so many other ways.

I am delighted to acknowledge many people for their contributions in getting this book out of my head and into publication. The most significant have been my three technical reviewers who have read and commented on drafts of each chapter as they have evolved: Neville Moray, Gerry Miller and Bert Simmons.

As Head of Department and Professor of Psychology during my undergraduate days at the University of Stirling from 1976 to 1980, Neville Moray bears a significant responsibility for my having chosen to seek a career in human factors. I had originally applied to the university to study marine biology[1] and only planned to take psychology as a "minor" subject for a year to fulfil the necessary credits. Neville's teaching sparked my interest in the psychology of human performance, and has sustained my professional career over the subsequent years. Neville patiently reviewed and provided sage advice on the academic and scientific content of the book where it was needed. His patience in dealing with my inability to use apostrophes is particularly appreciated. Any scientific errors that remain in the book are entirely my own.

Although I narrowly missed the opportunity to work with Gerry Miller some years ago, I have respected and admired his work for a long time. Gerry is the most prolific writer and producer of guidance, cases studies and other material on the application of human factors to the design of offshore platforms, as well as marine and other industrial systems I know. His reputation among those knowledgeable about human factors in the oil and gas and maritime industries in the United States is second to none. Gerry enthusiastically accepted the invitation to act as one of my reviewers, and has provided detailed and thorough comments and suggestions on every chapter. He generously offered more examples, photographs and stories from his seemingly endless collection

[1]My ambition was to work for Jacque Cousteau on his research ship Calypso.

when he thought they could illustrate and support my narrative than I had room for. In various places in the book I refer to "an HFE specialist." Often, Gerry was that specialist.

In 2005, Bert Simmons was, perhaps reluctantly, thrown into the position of overseeing the implementation of HFE on one of the largest capital projects the oil and gas industry had undertaken up to that point. At the time he had nearly 30 years of experience as an operator. Bert quickly realized that HFE offered the opportunity to influence thinking about the design of the new plant in order to ensure that the generation of operators to follow him would not experience the design-induced frustrations, risks and discomforts that had been a daily part of his own working life. Since then, Bert has completed HFE training and has developed into a very capable HFE practitioner in his own right. I have greatly valued Bert's comments and suggestions on the text, as well as his willingness to share personal stories and experiences that illuminate and illustrate the themes of the book.

I am deeply indebted to many other people for their suggestions and comments on drafts of specific parts of the book, as well as for their support and encouragement to complete the work. My friend and former colleague Johan Hendrikse has been a constant source of support and encouragement since the book was originally conceived with Harrie back in 2007. Johan is among the most committed, most experienced and most self-effacing human factors professionals I have had the pleasure to work with. I owe him a great debt for everything he has taught me about the physical ergonomics of oil and gas facilities. If anyone (other than Gerry Miller) knows more about the ergonomics of valves, stairs and ladders, not to mention the many other pieces of hardware that keep the industry going, I have yet to meet him. In the book's original conception, Johan would have been a joint author, or at least significant contributor. It would have been a far finer work if he had been able to contribute fully.

I am also grateful to John Wilkinson, John Thorogood, Barry Kirwan, Kirsty McCullogh, Cheryl MacKenzie, Gordon Baxter, Dal Vernon Reising, Colin Grey and Colin Shaw, among others, for their comments and suggestions or for suggesting material to support individual chapters or sections.

The book was largely written in two libraries. I'd like to thank the University of St. Andrews for allowing me access to its library, as well as the City of Glasgow for the wonderful Mitchell Library. I am also indebted to Heriot-Watt University, where I hold an honorary position, for access to the university's on-line information services.

Last, but far from least, I am indebted to my family, Kath, Fraser and Ross, for their love and support. And simply for being themselves.

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