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Book Review

So You Want To Be An Engineer?

By Gareth Davies Padfield

Reviewed by David G. Harding

If you want to be an engineer – but want to know what you are letting yourself in for – what better way to learn than sitting down with one? Particularly one who has lived a long fruitful life in the profession, and is passionate about it. All the more, one who has lived through the development of a new, demanding and important field? If you can't do that, then the next best thing is to read Dr. Gareth Padfield's book: *So You Want To Be An Engineer? A Guide to a Wonderful, Mysterious Profession, With Sketches from an Aeronautical Engineer's Album*.

This is an extraordinary book that is really several books in one. Although the focus is to address the engineering student, the book is also an autobiography of an industry-leading technologist and educator.

It is additionally a superb textbook, starting with basic engineering principles, then exploring applications in the field of helicopter engineering, with particular focus on stability and control technology. Furthermore, it contains the history of these subjects, starting with the Wright Brothers through today's simulation, automation and virtual prototyping.

Padfield emphasizes the human and political life of engineers with discussions of group collaboration and dealing with customers, with insights from his career at Westland Helicopters, the Royal Aircraft Establishment, etc. He particularly highlights the challenges of addressing user needs within technical limits and realities. These are illustrated with case studies, both successful and unsuccessful. Finally, Padfield describes his second career as an engineering professor and head of the engineering department at the University of Liverpool.

All these elements are woven into this book; consequently, it is a good read for almost any member of AHS International.

The Spark

A flight test course at the College of Aeronautics (now Cranfield University) fired Padfield's spark, or as he calls it, his Damascene Moment. Actual flight experience and the associated data analysis came together to provide the spark. The spark that illuminated the insights derived from the mathematics of the physical process. Mathematics was to be the backbone of his subsequent accomplishments.

That this was associated with aircraft stability was a key vector in his subsequent career. His final year project, "the stability of aircraft under constraint," led to the broader interest: stability and control.

The enthusiasm and energy stimulated by these experiences resulted in an offer for a postgraduate research position in which he made significant contributions to the understanding and analysis in the field. This in turn led to a position at Westland, where his energy turned to the helicopter: "one of the most complex machines man has created."

His expectation was, "surely, since we made it, we must understand it." Finding this was not the case opened the field of challenges which encompassed his work for the next thirty years, first at Westland and then the government research laboratories.

Engineers and Newton

Padfield starts the technical part of an engineer's life with Newton's Second Law, $F = ma$, tantalizingly depicted as $F \approx ma$. It is the introduction to a chapter leading to basic helicopter physics and the inviolable relationships in the various key tradeoffs. He explains that "engineers usually have to work with approximations to find solutions to problems that allow them to design and build machines." This is described as "bending the laws":

> Engineers are good at finding approximations and good engineers also know just how much the laws can be bent before the approximations no longer work, before assumptions are no longer valid. When operating, engineered machines obey the laws of course, but their evolution is one of refinement and optimization, as the bends gradually get ironed out.

The Wright Brothers are singled out as preeminent engineers on all counts. We all know them as the first to fly, and some know that their key finding was the invention of control through wing warping. Fewer know that the key to successful control of their machines was the incorporation of three axis control, including the coupling of rudder with wing warping; all their early machines were controllable but unstable.

The Wrights conducted a vast array of experiments leading to their successes, all of which were thoroughly documented. In his later career as a university professor, Padfield had a PhD student study these materials. This included conducting stability and control analyses of their various airplanes, then "flying" them on the university's simulator. They thereby experienced the Wright's flying quality achievements made at Kitty Hawk and Huffman Prairie.

Design Requirements

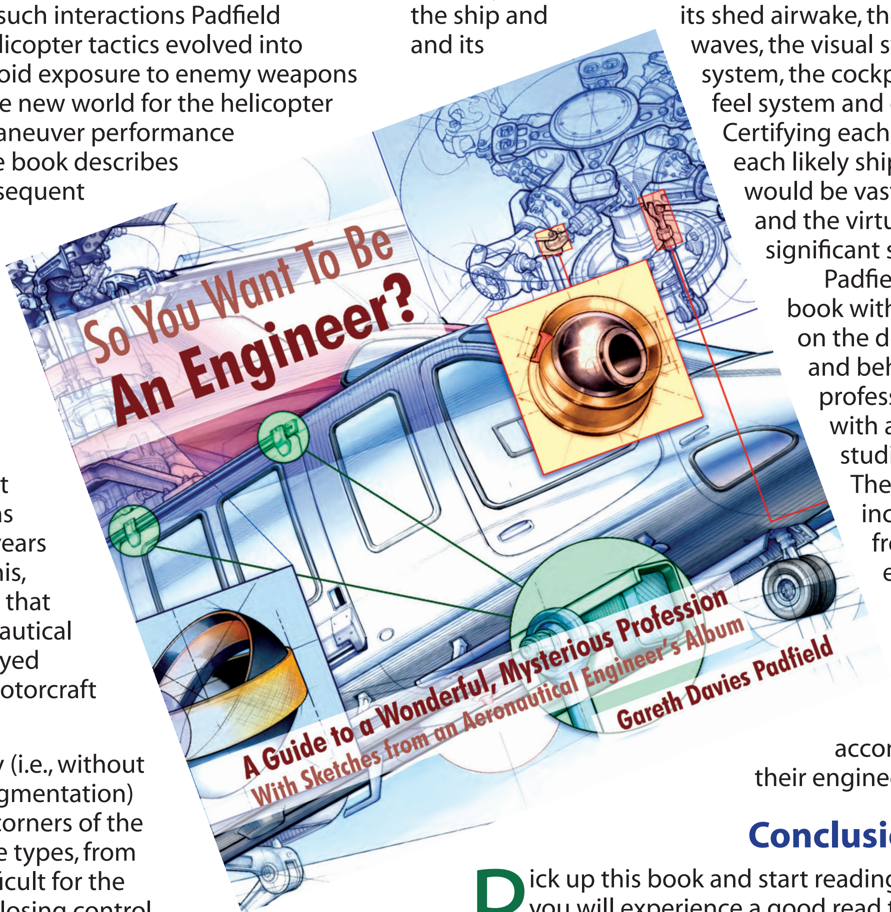
Padfield spends a good deal of the book examining real engineering problems and projects, and in so doing draws in the human side of the process – interactions within teams and with customer, users and managers where different language introduces uncertainty, errors and mistakes. They also introduce opportunity for understanding and invention.

One particular series of such interactions Padfield discusses are when Army helicopter tactics evolved into nap-of-the-earth flight to avoid exposure to enemy weapons and sensors. This was a whole new world for the helicopter designer in terms of both maneuver performance and stability and control. The book describes these meetings and the subsequent analyses, experiments and design tradeoffs that followed. The government laboratories, military services and industry worked together to develop solutions to this new challenge.

Padfield was invited to write a retrospective account of how this sub-discipline has developed over the first 70 years of rotorcraft operations. In this, he described the critical role that the jointly-developed Aeronautical Design Standard ADS-33 played and will continue to play in rotorcraft design. He states:

> Helicopters are naturally (i.e., without any artificial stability augmentation) unstable and there are corners of the flight envelope, for some types, from which it can be very difficult for the pilot to escape, without losing control. When the visual conditions degrade and the pilot has difficulty seeing the terrain and horizon references, there is a high risk of spatial disorientation, with consequent departures from the desired flight trajectory. Having clear, evidence-based standards that help users specify what they need and guide manufacturers to make quality products, is really so very important in engineering.

This history and associated technology is discussed in some depth.



Simulation and Virtual Engineering

Simulators became an integral part of Padfield's career from the earliest days. Many of his technology development activities involved their use. The increase in fidelity and scope of flying qualities problems for which they have been applied is discussed in some detail and many examples explored. The discussion of growing simulation fidelity and scope leads to a chapter on the broader virtual world. Padfield discusses the rapidly expanding field of virtual engineering from computational aerodynamics that now enables the virtual prototype in the virtual factory – including manufacturing processes. He describes how these analyses allow for discovery of design flaws much earlier in the design process with substantial savings in downstream costs.

A particularly effective virtual engineering (VE) test and evaluation activity is described in the Joint Ship Helicopter Integration Process. JSHIP aimed to simulate the process of landing and takeoff from ships while in the wake of the ship and sea effects, thereby significantly reducing the amount of flight testing. "Bringing this piece of VE together required a variety of components; the aircraft and its shed rotor wake, the ship and its shed airwake, the sea surface and its waves, the visual system, the motion system, the cockpit with the control feel system and displays, etc." Certifying each helicopter against each likely ship by actually flying would be vastly cost prohibitive and the virtual analysis made significant savings.

Padfield concludes the book with several sections on the desired processes and behaviors of the professional engineer with a series of case studies and examples. The final section includes "sketches from Liverpool engineers" – the stories of some of his Liverpool students' accomplishments in their engineering careers.

Conclusion:

Pick up this book and start reading at random and you will experience a good read that may remind you of your career experiences, or just be a good story. But there is so much good material in this book that it really deserves to be read from beginning to end, particularly if you are an engineering student. It is indeed, as Padfield claims, "A Guide to a Wonderful and Mysterious Profession".

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About the Reviewer

David G. Harding began his career as an apprentice with Hawker Aircraft Company in 1955. After graduate studies at Imperial College in 1961, he moved to Boeing Helicopters. Harding retired in 2001 as Director of Future Programs, for Boeing's Phantom Works. For the last five years, he has been mentoring engineering students.