Book Review

Reviewed by Alfonso Farina and Silvia L. Ullo*

Email: alfonso.farina@outlook.it
Email: ullo@unisannio.it
*Corresponding author

Human-in-the-Loop. Probabilistic Modeling of an Aerospace Mission Outcome
by: Ephraim Suhir
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The book *Human-in-the-Loop* by Professor Ephraim Suhir deals with manifold methodologies for predicting, and therefore controlling, reliability issues of complex systems, with a specific focus on aerospace missions. More specifically, the prediction of failures of equipment-and-instrumentation components, as well as those related to human operators, represents, de facto, a keystone for modern complex aerospace missions design.

The main idea of the author is that assessing several critical uncertainties via statistical methods allows for determining the likelihood of a mission failure, which in turn, is strictly correlated to the capability to design ideal boundary conditions for a mission.

Accordingly, the book comprises nine chapters, sketching mitigation measures along with several case studies, which, oftentimes, allow extending paradigms and methods beyond the aerospace domain.

After the introductory Chapter 1, the book develops along the following chapters.

A recall of fundamentals concepts of probability and applied examples are illustrated in Chapter 2, where the main distribution functions for random variables and processes are presented. In this chapter, the Bayes formula is introduced as a technical diagnostics tool, along with the beta-distribution as a tool for updating the reliability information. In this framework, both tools represent a first approach to the problem addressed in the book. Particularly interesting is also the introduction of ‘extreme value’ distributions. The ‘extreme value’ is defined as the largest value expected to occur in a limited number of observations, or in a limited time interval. The probability density and cumulative probability functions of the extreme response random variable are expressed in terms of related basic distributions for the ordinary, non-extreme cycle of loading or work. This allows analysing the response of systems or humans when the workload exceeds standard situations.

Application of these concepts are then illustrated in Chapter 3, where the extreme value distribution (EVD) techniques are applied with probabilistic modelling to the case of a helicopter undercarriage strength in a helicopter-landing-ship (HLS) situation. The aim is to quantify, on a probabilistic basis, the role of the human factor in such situations, to assess his or her reliability, since nobody and nothing is 100% predictable. The extraordinary part of the book is in the simplicity adopted by the author for presenting topics that are certainly not simple. For instance, this is the case of the calculation of the probability of safe landing on a ship's deck, helping in defining "the condition of safe landing in a quite simple way", using Prof. Suhir's words.

Chapter 4 tackles the 'Fundamentals of probabilistic aerospace electronics reliability engineering', by showing how the recent probabilistic design for reliability (PDfR) concept can be effectively employed in making an electronic or optical device turn into a reliable and marketable product. An important question is related to the failure-oriented-accelerated testing (FOAT) topic and highlights how one should establish the list of crucial accelerated tests (ATs), the adequate physically meaningful and realistic stressors, and their combinations levels in order to improve existing practices. The major principles of PDfR are illustrated in the 'ten commandments', which remind how a product is affected by a never-zero probability of failure. To assess the seriousness and the likely consequences of a detected failure, different models can be chosen: a statistical model, a physics-of-failure BAZ model or a combination thereof. The BAZ model, representing the worst-case scenario, allows using a three-step concept (TSC), where first, the Bayes formula is implemented to identify the faulty or malfunctioning devices; the BAZ model, or an extended version of it, is then used to assess the remaining useful life (RUL) of the product; and then a final step is implemented on a tree-based rule.

Chapter 5 tackles the 'Probabilistic assessment of an aerospace mission outcome' merging the issues from several other chapters. It introduces the double-exponential probability distribution function (DEPDF) to quantify the likelihood of a vehicular mission success and safety, due to imperfect instrumentation or the insufficient human capacity factor (HCF) under off-normal level mental workload (MWL).

In Chapter 6, a probabilistic risk analysis (PRA) approach based on the DEPDF is suggested as a suitable quantitative technique for assessing the probability of the human no failure in an off-normal flight situation.

Two cases are chosen to illustrate the correctness of the approach: the 2009 US Airways 'Miracle-on-the-Hudson' successful landing and the 1998 Swissair 'UN-shuttle' disaster.

Again, in Chapter 7, the DEPDF is used, in this case for the so-called 'Two men in a cockpit', to evaluate the likelihood of the contingency of an extraordinary event, such that, for instance, when one of the two pilots in an airplane cabin becomes incapacitated, while the other pilot might have to cope with a highly stressed situation and a high MWL.

Chapter 8 underlines significant potential attitudes for reducing aeronautic casualties through the operator's perspective. It comprises Cellier's definition of anticipation: "an activity consisting of evaluating the future state of a dynamic process, determining the time and timing of future actions to undertake, and mentally evaluating these actions." Accordingly, the total anticipation time is evaluated by splitting it into three different time periods whereas the probability that the anticipation time exceed a certain level is computed as well.

Finally, in Chapter 9, the DEPDF is used to assess human no failure. In addition to the MWL and HCF, the possible role of the current (measured/monitored) human's state of health (SH) is also taken into account. Moreover, in this chapter, considerations on ergonomics of the workplace are made; whereas, it is observed how improvements in various aerospace missions can be obtained through an amelioration of the work environment, as well as other well-established human psychology means that may affect the operator's performance.

In summary, the book *Human-in-the-Loop* by Professor Ephraim Suhir is a remarkable effort to outline reliability issues of modern manned and unmanned complex systems in the aerospace sector taking into account a variety of methodologies and presenting several case studies. The *Human-in-the-Loop* paradigm also paves the way for smart cross-fertilisation's with closely related fields such as radar. Within this framework, it is worth pinpointing the companion reference book: *The Impact of Cognition on Radar Technology* edited by Dr. A. Farina, Prof. A. De Maio and Prof. S. Haykin (2018, Scitech Publishing) where the concept of cognitivity and perception-action-cycles ponder on the role of autonomous machines, to a certain extent as a complementary archetype, in a close intertwinement with the role of humans.

Our strong recommendation is to have the book at hand on the shelf to be continuously inspired to an 'open-minded' evaluation of the impact of human in the loop and related mitigation theories developed in the book for air space systems.