Preface

"I shall conduct the reader over the road that I have myself travelled, rather a rough and winding road, because otherwise I cannot hope that he will take much interest in the results at the end of the journey." Albert Einstein[1]

This book is about the journey over the road I have travelled since birth till today, but it is not a book about me, this is a book about the quest for the new body of knowledge, which was named MIRCE Science, by me, without reasonable excuse!

According to my mother I loved the smell of petrol whilst still in her womb. Hence, my childhood was dominated by a love for cars and everything related to motorsport. For me, a year was the measure of time between two Formula 1 Monaco Grand Prix races. With the passing of the years my attention gradually drifted towards the Monte Carlo Rally. I found totally irresistible the challenge of driving as fast as possible for hours and days on many different road surfaces, continuously facing numerous challenges, from traffic conditions to system failures, while following the strict time table governed by the rules and regulations. While attending secondary school I got involved with the maintenance of my father's car. In my mind that brought me closer to rallying, where the principal axiom is: crossing the finish line. Hence, from a very early age I learned the relationship between reliability, maintenance and crossing the finish line.

In 1971, when the time came to choose a university subject, I had no dilemma. The Faculty of Mechanical Engineering was the place where I expected to learn how to design reliable cars and how to maintain them, thus crossing the finish line, on time, at the end of a rally. While studying mechanical engineering I started rallying in a car that I assembled by hands, in the neighbours' garden, from parts obtained from Belgrade's scrap yards. Not having any car manufacturer's sponsorship, in addition to the cost of competing, I had to look after the preparation and maintenance of the car, with an almost non-existent student's budget. Hence, the origins of the question that has tormented me for years: which spares to purchase? For example: a fuel, water or oil pump, as each of them requires different tools for replacement and have different consequences on my quest for crossing the finish line. The more integrals and differential equations I solved, while studying thermodynamics, fluid mechanics and many other subjects, the more I realised that a mechanical engineering degree will not equip me with the knowledge required to address my challenge, which was how to maximise my chances of crossing the finish line, with the resources that my budget allowed.

After graduation I started working as a research and development engineer in industry, while "privately" continuing the quest for the knowledge that is needed to provide the solutions to my quest. This journey took an additional three years of studies for the Master of Science in Maintenance Engineering (Appendix A). Still not satisfied, I spent a further 5 years doing research that culminated in the award of the Doctor of Science in Reliability Engineering (Appendix B). Both degrees I obtained from the Faculty of Mechanical Engineering at Belgrade University. By this time I had stopped rallying, without finding the solution to my quest for crossing the finish line. Undeterred, I went

[1] Proceedings of the Prussian Academy of Sciences, Cosmological Considerations on the General Theory of Relativity, Vol. X, 1917 (p. 142)

to Exeter University in the UK, to continue the quest, while learning English, which would enable me to: access the body of knowledge contained in the western-world Educational Institutions and also enable my use of computers.

After several extremely demanding but immensely enjoyable years, totally devoted to research, my professional breakthrough came. For this I have to thank the visionary Director of the School of Engineering, Professor John Flower. He gave me the opportunity to start teaching Reliability and Maintenance Engineering to second year undergraduate students of Engineering Science. This was exactly what I was hoping to learn when I had been in their position. This new development inspired me to work even harder on solving my quest for crossing the finish line. During the years, at Exeter University, I came to the realisation that the rest of the world has very similar problems to rally drivers. For example, the transportation industry is also driven by the strict time scheduled delivery of departures and arrivals of aircraft, trains, buses and ships. Manufacturing and production organisations have to cross their own "finish line" set by various stakeholders, at the end of each day, week, month and year. With that realisation I established a self-financing Research Centre for Managing Industrial Reliability, Cost and Effectiveness, M.I.R.C.E., at the School of Engineering, in 1988. Very quickly the Centre attracted industrial sponsorship, and started running research projects, scientific symposia, and training sessions. In 1991 we offered the world's first Master Programme in Logistics Engineering, from the School of Engineering, which was followed by the Master Programmes in Reliability and Maintainability Engineering (1996) and finally in 1997 a Master Programme in System Operational Effectiveness. All the activities within the Centre[2] generated a new body of knowledge towards the final solution to my quest for crossing the finish line. Some of them were presented in my book, "Reliability, Maintainability and Supportability - A Probabilistic Approach", published by McGraw Hill in 1993.

I earned my salary at Exeter University by fulfilling all the contractual obligations regarding the undergraduate degree courses, at the School of Engineering. To broaden young students' horizons and motivate them to dream about big engineering creations, during the dark and cold winter months, I started giving Evening Lectures related to Boeing 747, Concorde, Ferrari F40, French High Speed Train (TGV) and similar engineering marvels. Then, while searching through material for those Lectures I came across a few articles related to the development of the new passenger aircraft, by the Boeing Corporation, known as the triple seven (777). The more I read the more I was impressed with it. Very soon, I learned about great Boeing engineers who were working on this project, like Neil Standal, Ron Ostrowski, Granny Frazer, Jim McWha, Henry Shomber, Tom Gaffney, Dale Hougardy, Fred Howard and many others[3]. The whole effort of the Boeing Company was orchestrated under the slogan "Working Together", coined by the inspirational project director Alan Mulally, who understood engineers, managers, contractors, customers, and, above all, the aircraft itself. Then, I learned that since 1916, when the first Boeing aircraft was produced, there has been a Chief Engineer and Chief Pilot for each model. However, on this occasion a new "Chief" was created, and it was the Chief Mechanic, whose job was to make the aircraft "maintenance friendly". This "discovery" totally changed my professional life forever.

---

[2] Ten Years of Achievement MIRCE 1988-1998, pp 232, edited by David Harvey, designed and produced by Ampersand Publicity, Exeter, UK, 1998.

[3] [3] Sabbagh, K., "21st Century Jet, The Making of the Boeing 777", page 84, Pan Books, London, UK 1996.

The more I read about the Chief Mechanic of the Boeing 777 (B777), whose name was Jack Hessburg, the bigger and bigger his stature became in my eyes and, naturally, I wanted to know more and more about him and his job. Based on what I read, in my mind, he became one of those rare people you describe as "larger than life". From the perspective of someone who learned through rallying that maintenance is an integral part of the life of any system, and as such needs to be considered from the moment a system is being conceived. Jack was doing exactly that on the B777, with the assistance of hundreds of first line mechanics from the world leading airlines, like United Airlines, British Airways, All Nippon Airways and a few others. Jack brought these mechanics into the design office to talk reality to Computer Aided Designers. When asked, to explain the maintenance philosophy of the B777, he replied, "All I want is to go to Cleveland on time and never crash." Immediately, I realised that he was the first design engineer who spoke my language, as in my short rally career all I wanted to do was to cross the finish line, within the allocated time, of course, without crashing. My professional "obsession" with Boeing's Chief Mechanic continued with exponentially increasing intensity. This was exactly what I had been searching for, during my engineering education and professional engineering career, but never found it, till now. My evening Lectures on the B777 were well received, as each year I had a student doing their final year project related to this aircraft.

All the pieces of my "B777 jigsaw puzzle" came together, for me, during the 1st World f Aviation Congress in Anaheim, California, 13th – 15th October 1997. There, during the three days, I met all three of my B777 heroes, Alan Mulally, Jack Hessburg and Gordon McKinzie, United Airlines representatives for the B777. The rest is history, partially described in the book.

Our meeting in Anaheim ignited and united Jack's and my lifelong passion for creating and maintaining systems that are destined to work in compliance with scheduled timetables, under operational pressures and with huge consequences for failing to do so, hour after hour, day after day, year after year. Jack accepted an invitation to visit my Centre at Exeter University and give a Lecture to the Members of the M.I.R.C.E. Industrial Club. On the 27th January 1998 he delivered his first Lecture at the Centre, entitled: "Airlines do not spend millions on aircraft to make roost for pigeons on vertical fin, fouling the logo". This Lecture totally shaped my life, and I am pretty sure that it heavily influenced each of the 125 attending professionals. During my student and academic life, I attended hundreds and hundreds of lectures, but none of them, neither before nor after, made such an impression on me. Jack confirmed the "larger than life" perception that I had of him. He delivered 90 minutes of smooth, interesting, intelligent, informative, philosophical, provocative, and authoritative presentation regarding his job as Chief Mechanic, the first and the only one in the world, without a single slide, notes, or any other teaching aid. The transcript of the full lecture is given later in this book, so future generations can learn about "Jack's" genius, from the words spoken by the man himself.

During the Lecture, Jack said, "Now, how do you get that equipment availability? There's a number of ways you can do it, but some of them have very, very expensive consequences. What you must have is an extremely high degree of reliability. I can do that if I put my designer's hat on, but the problem is, you're not going to like the price. I'll give you 100% departure reliability as a VP of maintenance at the airline, even if you Boeing, don't do it, I can still do it, because I'll throw enough parts and people at it and I'll give you 100% departure reliability that I'm broke in a week. So I am

immediately, as in all design work and engineering work, faced with the business of compromise, I have to trade cost 'producibility', my own costs, with a degree of reliability. Now we have to start thinking about, where I'm going to have to start making these trades. That's a cute stunt."

As a student who self-financed his rallying ambitions, I fully understood every single word Jack said, and their implications. Then, he continued by saying "So now, I as a designer, and I have to fill my customer in as well, I have to decide where I'm going to put economic redundancy into my design, because it costs money. We have really not developed the discipline where we know how to normalise that, yet. But you begin to put those into the design. What happens? Between a Minimum Equipment List, a basic decision on the degree of reliability of the device and economic redundancy, if you hit the right combination, you should never find the vehicle in a position where it is not able to fly because you have intruded upon airworthiness. But, by the way, don't spend so much money; because I'm paying extra for these things, I'm going to be carrying it for the next 20 years. If you have the full answer to that, would you please see me after this meeting! There's a Nobel Prize in it." These words have been governing my life ever since, because it was exactly that type of knowledge that I was hoping to gain from my University Degree Programme, but had not. There was nothing wrong with the Mechanical Engineering Degree Programme I studied; all that was wrong were my expectations from it. Mechanical Engineering Programmes have not been designed to even address this type of knowledge. Furthermore, I discovered that a University Degree Programme, which would deliver this type of knowledge, does not exist anywhere in the world!

The following decades of my professional and personal life have been driven by the search for the solution to my quest for crossing the finish line, boosted by Jack's "Nobel Prize Hint". For me, it was the most significant revelation: my rallying dilemmas have been pushed back by Jack, into the design office, where much more could be done than merely managing what spare parts and tool selection to bring to the starting line. This brought my life's obsession with car rallying and my professional focus on mechanical engineering design, together in such a natural and logical way thanks to Jack. That realisation, with the added incentive behind the "Nobel Prize Hint", put me into a very challenging, professional and personal situation. My academic standing was very high and I was well respected by the world leading defence and aerospace organisations, which were regularly sending students to my educational programmes and training courses, which were praised by external examiners and well respected by the students themselves. For many of them this was the pinnacle of their professional education. However, truth be known, I knew that my exploration of all of these issues, although important and connected, were nowhere near sufficient to address Jack's "Nobel Prize Hint". Fully aware that the entire operation of the Centre for M.I.R.C.E. during its 10 years of existence was self-financed, gave me the strength to start thinking of the unthinkable. That was to take a "plunge", leave Exeter University and establish an independent organisation, exclusively dedicated to the development of science based knowledge that would provide the solution to my original quest for crossing the finish line and inevitably win the Nobel Prize, because its applications will be found to be "the greatest benefit to humankind" in the year of discovery.

"Fast forward", I decided to resign from Exeter University and founded MIRCE[4] Science Limited as an independent institution, to engage in scientific, educational, training, literary and professional endeavours related to the development of the scientific body of knowledge required to provide a solution for my quest for crossing the finish line, and personally respond to Jack's "Nobel Prize Hint". To my great pleasure and pride, on the 25th May 1999, the MIRCE Akademy[5], was officially opened by the great Jack Hessburg himself in Woodbury Park[6], about 6 miles from the city of Exeter. At the University of Exeter, all the undergraduate degree courses I had been teaching and the postgraduate Programmes offered by the Centre for M.I.R.C.E. were discontinued. The following day, Nigel Mansell[7], who fully understood and supported our quest for the scientific solutions to the problems that caused his 108 DNF (Did Not Finish) out of 187 Formula 1 Grand Prix races, delivered the Inaugural Lecture[8] of the Akademy.

Consequently, the scene was set for the search for the body of knowledge to fully address and ultimately conquer the quest for crossing the finish line. The more time that passed by, the more I realised the brutal truth of the Einstein's statement: "A theory can be proved by experiment, but no path leads from experiment to the birth of a theory." I have experienced many in-service phenomena and had learned about many more through literature, but I could not find anything to guide me to the road towards the birth of a theory. That was the dilemma the MIRCE Akademy faced during the early years of this century. Despite putting in hours, months and years of extensive research and hard thinking, we could not find the correct path forward. In moments of "desperation" I calmed myself by saying that even the great Jack Hessburg, who created the role of Chief Mechanic, its job description and then finally delivered the "maintenance friendly B777", did not have a name for "this discipline", which is how he had to refer to it in his Exeter University Lecture. Even further, the realisation that, to the best of my knowledge, the mighty Boeing Corporation that has all the departments necessary for the advanced research, development, design, manufacturing, certification and customer support of their numerous products, have not yet developed a body of knowledge to deal with "this discipline", made me fully conscious of the height of the mountain to climb!

I knew, from the outset, that some physically observable characteristic(s) that would reflect the overall "reason for existence" of functional systems have to be created in order to quantitatively determine measures of their ability to continue to function, or their functionability if you will, that quantifies their in-service behaviour. This was a crucial problem that I had to resolve, but the most difficult one, by far. There is no question that, from anybody's point of view, in say the aircraft design office, the reason for the existence of an aircraft is to deliver passengers and cargo from A to B through the air, with the best possible functionality performance (maximum speed and minimum fuel consumption for a given payload at the minimum overall cost). Generally speaking some of these parameters could be quantified, for each aircraft type by a single number known as the "power to weight ratio", which it is possible to accurately predict with the existing knowledge of aeronautical engineering, but

[4] MIRCE Trade mark, No. 2338979 has been registered in Great Britain and North Ireland, to the name of MIRCE Science.
[5] MIRCE Akademy is a division of MIRCE Science Limited Company registered in England and Wales.
[6] Woodbury Park is a magnificent 500 acre complex set among rolling hills above the South West English coastline, only a few miles from Exeter.
[7] Nigel Mansell OBE, 1992 F1 World Champion, 1993 Indy World Champion.
[8] Knezevic, J., From Zero to One, Nigel Mansell's Journey, pp 32, MIRCE Science, Exeter, UK, 2000.

conveniently omits the cost element (procurement and operational). At the same time, there is no question, from anybody's point of view, in the Board Room of any Airline that the main reason for existence of an aircraft is to "generate profit", which is only possible by delivering all scheduled flights "on time and never crash", with a minimum demand on procurement, operation and maintenance resources. All of these words could be quantified, for each passenger aircraft type, by a single number known as the "dollars per seat per miles", which is measured and summarised by each airline in their operational statistics, many decades after the aircraft design was completed.

Hence, I understood, extremely well, what the Chief Mechanic's job was in the design team. However, I also understood, equally well, that, while doing his job, Jack did not have a proven body of knowledge to rely on, which was equivalent to the body of knowledge contained in aeronautical engineering, extensively used by his colleagues. Of course, what Jack as an individual had, from my point of view, was unparalleled in-service experience, total devotion to designing "aircraft that go on time and never crash" and personal integrity to publicly declare the necessity for the new "discipline", worthy of the Nobel Prize. In summary, as I saw it very clearly, while the body of knowledge contained in the aeronautical engineering predicts "power to weight ratio", the body of knowledge that I was seeking, should be able to predict "dollars per seat per miles". Although "the penny had dropped", regarding what has to be done, the huge question mark for me was how to do it?

Needless to say, I was fully aware that there were a large number of specialist system engineering disciplines that address and deal with specific characteristics of systems, like reliability (usually quantified through the Mean Time Between Failures, MTBF), maintainability (usually quantified through the Mean Time To Repair, MTTR), supportability (usually quantified through the Mean Time To Support, MTTS), availability (usually quantified through the inherent Availability, A_i, or operational Availability, A_o) and similar. In this context the curricula of many educational and training programmes were established and delivered all over the world. Of course, I would be the first to say that the educational programmes and training courses, which we ran at Exeter University, were exactly the same. Unquestionably it was correct for those who wished to specialise in these disciplines. However, despite the fact that all of these specialist subjects and their measures have their own specifications and design requirements, there was nothing to "normalise" them and define overall in-service performance of a system that would indicate how many daily flights "to Cleveland" are expected to be delivered "on time" and do not result in a "crash" during the in-service life of the given aircraft type, which are the main drivers of the "dollars per seat per miles" figure.

While I was thinking hard about that all embracing in-service performance characteristic that quantifies the "purpose of existence" of a functionable system, I received an email from a classmate, from XIII Belgrade Classical Gymnasium asking me to write a few pages for the book "Collection of Memories (1967-1971)" that was going to be published as part of the celebration of the Anniversary of our matriculations. During the following weekend I "transplanted" myself into those beautiful and indeed memorable years of my life, recorded them in a 12-page essay and emailed it to Belgrade.

Subsequently, throughout the following few days, happy memories continued coming back to me. One of them was the matriculation exam in physics, where the very first

question was related to the concept and units of work in physics. I still remember every single word written in my notebook related to work that says "In physics, work is considered done when an object is moved over a distance by an external force applied in the direction of the displacement. If the force is constant, work may be computed by multiplying the length of the displacement by the force acting along the path." Suddenly I realised that the concept of work presented to me almost 40 years ago, and accepted by me as a given truth, could be the starting point for solving my quest for crossing the finish line, invigorated by Jack's "Nobel Prize Hint". It became crystal clear to me that the purpose of the existence of every system that humans have ever created is to do something, as it is inconceivable to me that something would be specified, designed, produced and acquired by somebody in order to do nothing. Finally, the "eureka" moment came, and I realised that the "purpose of existence" of any system is to do the work. To differentiate the concept of work in physics and in "my science" the latter type of work I named, as the functionability work. Immediately I realised, that functionability work is considered done while a system is delivering its expected function over time, in a similar way to classical physics, where work is considered done when an external force is displacing an object over distance[9].

Consequently, in "my science" the concept of functionability work, as far as I was concerned, should be classified into the following two types:

- Positive Functionability Work (PFW): a generic name for the physically measurable performance of a functionable system type proportional to the duration of the calendar time during which the expected function(s) are performed, measured in hours [Hr].

- Negative Functionability Work (NFW): a generic name for the physically measurable performance of a functionable system type proportional to the duration of the calendar time during which required positive functionability actions are performed, measured in hours [Hr].

After several months of self-celebrations for having discovered the concept of functionability work in "my science", the way forward became much clearer. For the very first time I saw the method for bringing together a "Minimum Equipment List, a basic decision on the degree of reliability of the device and economic redundancy", which are Jack's design options for "never finding the vehicle in a position where it is not able to fly because you have intruded upon airworthiness." Needless to say that the same logic applies to my quest for crossing the finish line, and all other business that have set up monthly or annual targets. Thus, from now on, design teams will have a single, all embracing, measure of the "goodness" of the design, regarding the in-service performance of their future systems. This practically means that each feasible design solution will be associated with positive and negative functionability work, accomplished in the direction of calendar time. Although I was extremely happy with the discovery, very soon it become clear to me that it was only a part of the solution to my quest for crossing the finish line. The reason being, these are in-service characteristics of systems measured by their users, which means that they will become known to the design team several decades after they have completed their design. The data I quoted in the Inaugural Lecture were statistics compiled by Pan Am over 22 years of flying the B747, rather than Boeing's predictions.

[9] Work of one Joule is done when a force of one Newton displaces an object for one meter. (J=Nm)

During the following months of the development of "my science" it became clear to me that the discovery of functionability work, as a measurable physical characteristic of functionability performance was not the end of my quest for the finish line, nor sufficient for Jack's "Nobel Prize Hint." There is a caveat that was described, by none other than, Jack himself, "By the way do not spend so much money, because I'm paying extra for these things. I'm going to be carrying it for the next 20 years." Translating into "ordinary English" it means that it is not enough to determine the design solution that will provide the maximum positive functionability work during the in-service life of a functionable system, because the main objective of any business is to stay in business, and for that to happen: revenue generated must be higher than the cost of doing the business. Again, in my view, nobody expressed it better than Jack when he stated, "Airlines are in the transportation business; Boeing, Douglas, Lockheed, Airbus, they're in the airplane business. You must keep equipment available! You can have the shiniest looking airplane in the world, the most remarkably engineered airplane in the world, it's an academic marvel, it's an engineering marvel, but if the damned thing is not at gate B3 in Chicago at 9:15 to originate the trip to Cleveland, forget it."

Having established the concept of positive and negative functionability work, I came to the realisation that it is essential to address the resources associated with realising them. For me, as an engineer and scientist, a monetary value of the physical resources used to generate the desired functionability work, constitutes the cost. This topic I studied as part of the research related to my Master Dissertation Thesis, (details are given in Appendix A). Consequently, in "my science" I established the concept of functionability costs, and then grouped them into following two general types:

- Cost of Positive Functionability Work, which is the monetary value of the resources used for doing the work, like personnel, material, equipment, facilities, energy and similar. Thus, a cost of doing positive functionability work could be measured for each system considered[10],

- Cost of Negative Functionability Work, which is the monetary value of all the resources necessary used for doing the work, like spare parts, trained personnel, material, equipment, facilities, energy and similar. Hence, the cost of doing negative work is a measurable quantity for each system considered[11].

Although I was not deeply interested in the finance/accountancy per se, I knew that functionability cost categories are very well monitored and accounted for, by the numerous departments and experts from organisations involved in operating systems, for financial, statistical and controlling purposes. However, I was fully aware that the order of magnitude of these costs is pre-determined by the decisions made in the design office at the very early stages of the system design process. Hence, there is a "life time"

[10] During the Founder's Lecture I stated that a Pam Am's Boeing 747, has flow 80,000 hours and consumed 273.000,000 gallons of fuel, which is only one our of hundreds and hundreds cost elements related to the resources required for a machine to deliver positive functionability work.

[11] During the Founder's Lecture I stated that a Pam Am's Boeing 747, N747PA, has consumed, among many others, the following resources: 2,100 tyres, 350 brake systems and 125 engines. Also, this cost category includes costs of personnel, material, equipment and energy used to replace the metal skin, on its superstructure, wings and belly which were done 5 times, numerous structural inspections performed to detect metal fatigue and corrosion, which consumed more than 9,800 individual X-ray frames of film and the cost of all resources needed for the replacements of passenger compartment and lavatories, four times.

difference between the time when the functionability cost is committed in the design office and the time when the functionability cost is recorded by the accountancy office of its user. This fact of life brought Jack and me together. He needed a "discipline" that would enable the design office to compare many feasible solutions regarding the new system type, and for the chosen one to inform the airline's accountancy office what the functionability costs are expected to be, rather than to "keep fingers cross for decades" in the hope that the final numbers would be good enough to realise repeated sales. Although I had understood Jack's "Nobel Prize Hint" in the early 1990s, nearly 20 years after my quest for crossing the finish line was facing very similar problems and consequences. This realisation had now triggered several decades of intensive research and thinking leading towards the creation of "my science", as a solution to it.

In summary, the philosophy of "my science" is based on the premise that the "purpose of existence" of any system is to deliver positive functionability work. This is associated with necessary resources like personnel, material, faculties, energy and so forth. The monetary value of resources consumed delivering the positive functionability work constitutes a positive functionability cost. Complementary, the negative functionability work is done while a system is in a negative functionability state and exposed to the actions required to recover it to a positive functionability state, which are associated with the necessary resources such as personnel, spare parts, material, tools, equipment, faculties, data, energy and so forth plus the cost of the positive work lost, constituting the negative functionability cost. At this point in the development of "my science", it became clear that its main objectives were not to develop methods for measuring and statistically analysing the functionability performance of systems, but to develop a body of knowledge that would enable designers to predict them for each feasible option, based on both sets of figures, and then to select the most favourable one regarding, as I saw it at the time, the "dollars per seat per miles" in conjunction with the "power to weight ratio" figures. To achieve that goal I decided to expose the in-service behaviour of systems to the proven methods of science and mathematics to:

- Physically observe and measure a functionability performance of functionability system types quantified through the positive and negative work done during their in-service life, together with the resources consumed in the processes[12], and to determine the patterns of their behaviour in the direction of calendar time.

- Scientifically understand the physical phenomena and human actions that govern the occurrences of functionability events[13] through the life of functionable system types to the level of dimensional fidelity spanning from the atom (10^{-10} metre) to the Solar System (10^{10} metre).

- Mathematically describe the observed physical processes of doing positive and negative functionability work through time by a given functionability system types, which are characterised by uncertainty, discontinuity, irreversibility, inseparability, and dependence on time, location and humans.

[12] Boeing 747, registration number N747PA, been air born 80,000 hours, transported 4,000,000 passengers, burned 271,000,000 gallons of fuel while receiving 806,000 maintenance man-hours and consuming: 2,100 tyres, 350 brake systems, 125 engines, among other parts, during the 22 years of in-service life, at Pan Am airlines.

[13] Any event, natural or induced, that impacts on the functionability performance of a given functionable system.

The journey, along the road described above, has generated a body of knowledge, that I named MIRCE Science. It is based on the scientific understanding of the mechanisms that cause the motion of a system through in-service states in the direction of calendar time. MIRCE Science comprises axioms, laws, mathematical equations and calculation methods that enable accurate predictions of the functionability performance of a given "future" system to be calculated. Hence, it is a scientific solution to my 40+ years quest for crossing the finish line and Jack's "Nobel Prize Hint" given at Exeter University Lecture in January 1998.

The latest developments regarding MIRCE Science dissemination activities related to the publications in scientific journals, professional communications through conferences and list of selected positive and negative functionability events that took place in the world during the last few years that I recorded and analysed in order to the scientifically understand the mechanisms that cause their occurrences are also presented in this book.

Tragically, towards the final stages of this long research journey, constantly driven by Jack's "Nobel Prize Hint", an email from our mutual colleague and friend, Justine Hale, arrived in July 2013 with the following content:

"Mr. Jack Hessburg has suffered a debilitating stroke and is currently unable to speak or interact with the world around him. This occurred almost 3 months ago. Jack is living in a rehabilitation Hospital, but has made little real progress towards being himself again. I am sorry to write with this discouraging news, but I knew you would want to know."

Within a week I re-arranged all professional and personal commitments and flew to Seattle, on board one of Jack's B777. By some magic, Jack recovered some of his mental capacity and we had the most memorable time together, between 08:00 and 20:00, during the three days I spent with him. Sadly Jack passed away two weeks after he addressed me, for the very last time, with the following words,"I am ready for you to go home."

Dr Jezdimir Knezevic
Founder & President
MIRCE Akademy
Woodbury Park
Exeter, UK

Post Scriptum: I have started writing a book on the "Mathematical Principles of MIRCE Science" which will contain all the knowledge required for the full application of the MIRCE Science theory to the design and management processes of transportation, communication, defence, aerospace, nuclear, medical, energy and many other system types, the origin of which are presented in this book.

Acknowledgment

"Thanks Jack[14] for the Nobel Prize Hint."

I wish to acknowledge the individuals who guided me, in their own ways, throughout the lifetime search for the body of knowledge that ended up in this book under the name of MIRCE Science. Thus, "mega" thank you to:

My Professors who over several decades gave me the knowledge, then became my lifelong friends and passionately supported my journey towards the creation of MIRCE Science, namely: Jovan Todorovic (1932-2016), Alexander Mihaylovich Seynin (1916-1995), Robert A.B. Leaper (1921-2014), John Flower, Chris A. Brookes (1934-2013), Ben. S. Blanchard and Richard F.W. Bader (1931-2012). Their individual affiliations and contributions to my educational and scientific life are very clearly described throughout the book.

Gordon McKinzie, whose huge contribution to the development of the Boeing 777 on the user's behalf impressed me so much, that in 1993, I joined the United Airlines frequent flyer programme. Thank you Gordon for constantly sharing your professional knowledge with all of us and being so helpful to me, starting with the "choreography" of my meeting with Alan Mulally, one of the presidents of the Boeing Corporation, in 1997 in California, through extremely beneficial advice regarding the initial conceptualisation of the book in the summer of 2015, which extended its completion for several months, and improved it considerably. Also, for making extremely constructive suggestions during the writing of the book, all of which were adopted with gratitude. Finally, for helping me to re-establish the contact with Alan Mulally, by now, retired CEO of the Ford Corporation.

Alan Mulally, whose engineering and management genius flourish, during the development of the B777, under the slogan "working together" made fundamental impacts in numerous directions, was so impressive that I read everything written about it, watched hundreds of times the 5 hour PBS Video on the 21st Century Jet[15] while showing them in over 30 countries around the world during the last 20 years of teaching. Even further, I would like to believe that the creation of the post Chief Mechanic is of Alan's making, although I could not find any evidence in written form, to confirm my "romantic" thought. Yes Alan, the "The data set you free[16]", as the experimental MIRCE Science has clearly demonstrated.

Polly Vacher MBE, for allowing the MIRCE Akademy to be an integral part of both her solo flights around the world, while raising money for the Flying Scholarship for the Disabled, her chosen charity. Through these flights we tested existing knowledge of the System Operational Science, and I realised how much more needed to be done. Hence, to create a theory that is able to incorporate all physically observed phenomena around the world, including the unpredictability and brutality of Arctic and Antarctic,

[14] John Gregory Hessburg (1934-2013)
[15] Public Broadcast Services Video, The Building of the 777, Part 1: To Design a Plane, Part 2: The Sum of Its Parts, Part 3: A Plane takes Shape, Part 4, Taking Flight, and Part 5: Countdown to Delivery.
[16] [16] Sabbagh, K., "21st Century Jet, The Making of the Boeing 777", page 84, Pan Books, London, UK 1996.

which took an additional 10 years of research and significantly shaped the foundation of MIRCE Science.

Professor Mike Pecht of CALCE Centre from University of Maryland, USA, whose work on Physics of Failures in electronics systems regarding overstress and wear-out failure mechanisms, has given me energy and strength to continuously refuse to accept the doctrine of constant failure rate, which has been dominating “best practice” approach by a majority of Reliability Engineers during last 60 years and to seek the scientific understandings of the mechanisms that drive occurrences of failure events.

Professor Arie Dubi (1945 - 2015) whose knowledge of the Monte Carlo method was absolutely crucial for the development of MIRCE Science, and who strongly believed until the last day of his life, that the MIRCE Akademy must succeed as an innovative research and educational Institution.

Luciano Pizziolo, Master of Science graduate from the M.I.R.C.E. Centre, Exeter University, who never stopped believing and supporting my long and rather lonely journey towards the creation of MIRCE Science.

Jelena and John Gill, personal friends and respected university professors of mathematics, who refused point blank to go through my functionability equations because I did not tie them to set theory. It took me an extra 2 years to do so, but having done it I realised how essential their action was for building the foundation of MIRCE Science.

Craig Keen, Vice President Aircraft Operability, who commissioned numerous research and training programmes from the MIRCE Akademy that he needed to run a training courses for the Airbus operations in France, UK, Germany and Spain between 2001-2012. These activities enabled me to analyse and test different elements of MIRCE Science with real life data and operability requirements for the new technology used in commercial and military aviation. In 2002 Craig hosted a one-day training course at Airbus in Filton, Bristol, UK, which Jack and I conducted. The honorarium for the day Jack kindly donated to the Flying for Disabled Charity supported by Polly’s Vacher.

Dr John Crocker, Tony Martin, John Thompson, Alex Mulholland, Chris Hockley, Rafael Zavala, Orlando Chiarello, Graham Robertson, John Hale, Chris Burden and Austin Dunn, who in various ways contributed to the development of the MIRCE Science by supporting the Membership scheme of the MIRCE Akademy, in various ways.

Students of the MIRCE Akademy who have been exposed to the certain elements of MIRCE Science, in one way or the other, during their studies at the MIRCE Akademy. Special thanks to Claude Hirtz, Stuart Peake, Ian Zaczyk and Antonello Marras who have been an integral part of the of continuous development of MIRCE Science, axioms, laws equations and methods, as a part of assignments of their Master and Doctoral Diploma studies.

Bianca Senna, who has shown strong interest and support on behalf of the Senna family, for my research that tried to prove that it must be possible to create scientific theory that is able to determine the outcome of thousands of inter-related physical and emotional phenomena that govern in-service behaviour of systems, as her late uncle

Ayrton Senna (1960-1994) had been making, instinctively and experientially, to the level of perfection that culminated in his 1988, 1990 and 1991 Formula1 World Championships titles for Drivers. I have an endless respect for his mental abilities to deal with the complexity of all interactions between functionability related phenomena during the Grand Prix racing seasons that I have been able to be capture and describe through the language of mathematics, for any functionability system type.

Katarina (1896 -1971), my grandmother, who on my 4th birthday asked me, "What is 2 frogs and 3 grannies?" When I answered 5, she asked me "5 of what?" This is something that "grown up" reliability professionals still have not learned, as even today Failure Mode, Effect and Criticality Analysis allows addition of, say 2 bird strikes and 3 corrosion caused failures, to be called 5 failures!

My mother Zana (1928-2003), whose endless lifelong love for me culminated in 1982 when she was the only person who encouraged me to go to Exeter University in pursuit of scientific research in reliability engineering, as without that life changing event MIRCE Science would have never existed, as my "baby". However, as the need for this body of knowledge is so obvious, it is inevitable that one day somebody would have done something in this direction!

My father Milija who, at the age of 92, continuously followed the progress of this book, while writing his owns, between painting and grass cutting with a scythe. During my childhood he "chiselled" the following sentence in my brain: "It is impossible to create a kingdom by lying on the sofa and smoking tobacco!" With age I respected it even more!

Lynn, my partner, whose positive functionability work kept me in a good "operational condition" for over quarter of century, which enabled me to spend hours, days and years in front of the computer screen, including many weekends!

Doctor Jeff Edelstein, Jack's nephew, who was instrumental in making sure that all correspondence messages to and from the numerous members of Hessburg family "go on time and never crash", and for their continuous help and support during the writing of this book.

Justin Hale, for keeping me informed about Jack's health condition during the last few months of his life. Without that crucial link I would have never said farewell to Jack, my professional hero and personal friend and without that, I am pretty certain, this book would have not seen daylight. Thank you Justin, from both of us!

Mr and Mrs Hawkins, the owners of the Woodbury Park, who between 2007 and 2016, were providing the best possible home for the MIRCE Akademy regarding all the needs of the students, members, fellows, conference participants and the staff. The tranquillity, hospitality and professionalism that guests and the staff of the Akademy are receiving from all the Woodbury Park were instrumental for the success of our research, education and training activities.

Theodora Sarakinou, the owner of the hotel Oassis in Kassiopi, a small town on the island of Corfu in Greece, who tried very hard to "turn me into an alcoholic" by offering me small glasses of Ouzo while I was working on this book at the hotel's

computer in the late evenings hours, and the smiles of her daughter Mandy during breakfast hours, which were warmer than the Mediterranean Sun, in a summer.

Vladimir Majstorovic, Master of Electrical Engineering and grandson of my mother's lifetime friend, Slavica Majstorovic, whose comprehensive research of the draft of this book, significantly shaped its current version.

Alex Mulholland, active contributor to the development of MIRCE Science, who also spent many hours trying to bring my "free-spirit" approach to the English language closer to a linguistically acceptable product!

Margaret Stringer, of the MIRCE Akademy, for retyping some parts of the text several times, as I was trying to achieve the best possible flow of the huge amount of interrelated information related to the creation of MIRCE Science. It was rather challenging and yet, enjoyable process for both!

Jezdimir Knezevic
Bickleigh
June 2017

Post Scriptum: Following Axiom 5 of MIRCE Science, I acknowledge that all grammatical errors and typos contained in this book are of my own making and I sincerely apologies to all proper English speaking readers for not doing a better job after 35 years of trying! However, I do sincerely hope that a pleasure of scientific and mathematical "brilliances" will offset the grammatical deficiencies, several times over!