Jezdimir Knezevic

The Origin of MIRCE Science

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Dr Knezevic is a world class researcher, educator and entrepreneur. Over 400 publications disseminated world-wide through books, papers, articles, monographs and reports are attributed to his name. He has been elected as a Fellow, Member or Official of many leading Professional Societies and Institutions worldwide, and actively involved in editorial work with the world's leading and prestigious referred journals and publishing houses. Dr Knezevic has received several international awards for the contributions to science and education.

In 1988 Dr Knezevic established a self-financing Centre for Management of Industrial Reliability, Cost and Effectiveness, M.I.R.C.E., at Exeter University, UK. The Centre has attracted over 3000 professional engineers and managers to training and Master of Science Degree Programmes in Reliability, Maintainability and Logistics Engeineering., generating an income over 3 million US dollars.

In 1999 Dr Knezevic started the development of the body of knowledge for prediction of the functionability performance of functionable system types, which he named MIRCE Science. To fully focus on the research he resigned from the Exeter University and established the MIRCE Akademy, at Woodbury Park, Exeter, UK. Under his leadership, the Akademy has educated thousands of professionals coming from Industry, Government and Military Organisations world-wide and runs internationally recognised Master and Doctoral Diplomas Programmes in MIRCE Science, Mechanics, Engineering and Management.

Dr Knezevic holds Bachelor, Master and Doctoral degree from Faculty of Mechanical Engineering, University of Belgrade, Yugoslavia. He shares life with Lynn, is passionate about motorsport, is challenged by the restoration of rusty, but beautiful Lancia rally cars, and enjoys living in a XVI century built thatched cottage in tranquil village of Bickleigh, Devon, England.

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Content

Acronyms in MIRCE Science

Acronym	Term
FSS	Functionability Sample Space
CDF	Cumulative Distribution Function
CLR	Cost of Lost Revenue
CNW	Cost of Negative Work
CPW	Cost of Positive Work
CSW	Cost of Support Work
CMW	Cost of Maintenance Work
FSS	Functionability Sample Space
Hr	Calendar Hours
KGT	Knezevic-Glumac-Team
MPFW	Mean Positive Functionability Work
MNFW	Mean Negative Functionability Work
MCNW	Mean Cost of Negative Work
MCPW	Mean Cost of Positive Work
MFF	MIRCE Functionability Field
MFW	Maintenance Functionability Work
MS	MIRCE Space
MU	Monetary Units
NFA	Negative Functionability Action
NFC	Negative Functionability Cost
NFE	Negative Functionability Event
NFS	Negative Functionability State
NFW	Negative Functionability Work
NMS	Negative Maintenance State
NMW	Negative Maintenance Work
NNE	Number of Negative Functionability Events
NPE	Number of Positive Functionability Events
NSS	Negative Support State
O(t)	MIRCE Operability Equation
PDF	Probability Density Function
PFA	Positive Functionability Action
PFE	Positive Functionability Event
PFS	Positive Functionability State
PFW	Positive Functionability Work
PRF	Profit
REV	Revenue
SFW	Support Functionability Work
T	Interval of Calendar Time from Birth
t	Instance of Calendar Time
TFC	Total Functionability Cost
TME	Time to Maintenance Event
TNE	Time to Negative Functionability Event
TPE	Time to Positive Functionability Event
TSE	Time to Support Event
y(t)	MIRCE Functionability Equation

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 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.

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

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 **M**anaging **I**ndustrial **R**eliability, **C**ost and **E**ffectiveness, 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.

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[4], United Airlines representatives for the B777. The rest is history, partially described in the book.

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[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.

[4] Gordon A. McKinzie -In December of 1990, Gordon was named to head the 777 Program after leading United's technical evaluation for a new wide body aircraft to replace the DC-10. As Manager of New Technology at the time, Gordon was also responsible for new aircraft acquisition programs and other development initiatives involving engines, avionics, and flight systems. Prior to my assignment, Gordon managed Operational Engineering, Flight

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

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Technical Standards, Fuel and Performance Control, and was United's first Factory Representative at Long Beach on the DC-10 program. While with United, Gordon has been stationed in San Francisco (three times), Chicago, Denver, and Los Angeles, but now calls Seattle (seventh move) the final destination! Prior to Gordon's 29 years at United, he was a Flight Test Engineer at Edwards Air Force Base on a number of supersonic fighter and V/STOL aircraft programs. Gordon was also involved in advanced design projects at Ling-Temco-Vought in Dallas working on tilt-wing transport concepts, and at Northrop in Los Angeles on F-89, T-38, and F-5 strike aircraft. Gordon holds Management and Engineering degrees from Claremont McKenna College and Stanford University. He is a Fellow and Distinguished Lecturer of the American Institute of Aeronautics and Astronautics, and a private pilot.

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[5] 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[6], was officially opened by the great Jack Hessburg himself in Woodbury Park[7], 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[8], 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[9] 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 conveniently omits the cost element (procurement and operational). At the same time, there is no question, from anybody's point of view, in

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

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[10].

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

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

1. 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].

2. 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.

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:

1. 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[11],

[11] 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.

2. 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[12].

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" 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:

1. 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[13], and to determine the patterns of their behaviour in the direction of calendar time.

2. Scientifically understand the physical phenomena and human actions that govern the occurrences of functionability events[14] 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).

3. Mathematically describe the observed physical processes of doing positive and negative functionability work through time by a given functionability system types, which are

[12] 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.

[13] 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.

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

characterised by uncertainty, discontinuity, irreversibility, inseparability, and dependence on time, location and humans.

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[15] 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[16] 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[17]", 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, 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.

[15] John Gregory Hessburg (1934-2013)

[16] 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.

[17] [17] Sabbagh, K., "21st Century Jet, The Making of the Boeing 777", page 84, Pan Books, London, UK 1996.

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!

Part 1: Quest for Crossing the Finish Line

> *"Creating a new theory is not like destroying an old barn and erecting a skyscraper in its place. It is rather like climbing a mountain, gaining new and wider views, discovering unexpected connections between our starting point and its rich environment. But the point from which we started out still exists and can be seen, although it appears smaller and forms a tiny part of our broad view gained by the mastery of the obstacles on our adventurous way up."*
> Albert Einstein[18]

"Why did he have to park his car in front of our house?" Asked a seven-month pregnant wife to her husband! "How do you know, lying in bed in a dark room that it is in front of our house?" replied the husband. "Can't you smell the petrol?"

Two months later the couple had their first child, a son named Jezdimir. During the coming years, I clearly demonstrated a love for cars and other technical systems. According to my mother, at the age of two and a half, walking home with my parents, I saw a Land Rover parked in front of the British Embassy in Belgrade, and insisted I must have a photo taken of the "jeep" and myself. In the mid-1950s, in Yugoslavia, hardly anybody possessed a camera. However, my "organic love towards cars" was stronger than any other natural necessity. The family "legend" said that I stood in front of the "jeep" for 5 hours, while the hunt for a camera was going on, without any words of complaint or desire for food, water or toilet. Finally, the camera was found and the photo taken, which shows a young boy with a huge smile and a clear expression of happiness.

During my whole childhood no toy lasted 10 minutes, max, as I dismantled it, including my sister's dolls, to see what was inside and how they worked! On numerous occasions my mother would say, that the best job for me would be to "manage a scrap yard".

The love for machines was present throughout my childhood and well supported by my parents. From the age of three I had my first tricycle that I considered as an extended part of my body. All winter I would ride it in the flat with assistance from my nana, which would necessitate moving chairs and all other obstacles in my way. At the age of four I started roller-skating and never stopped, yet! The sturdiness of the metal frame and the wheels that were attached to my feet by bright red leather belts impressed me no end. Every free moment of every day I was out on the pavement skating with my friends or just by myself. At the age of five my mother bought me a beautiful blue bicycle in Venice. That started the new era in my life. Pneumatic white tyres, front and rear brakes, dynamo for the front light and the red reflector on the back, gave me extra hours of enjoyment. Very quickly, with help from the older boys in the neighbourhood, I learned how to maintain the correct tyre pressure, lubricate the drive chain, adjust the brakes and similar maintenance tasks. My own toolbox consisted of one universal bicycle spanner and one screwdriver. Pliers and other tools I would borrow from my friends, but with ambition to have my own one-day. Hence, it was very easy to choose birthday and New Year presents for me.

My family bought our first car when I was the age of eleven. I went with my father to collect their Skoda 1000 MB from the dealer and as the "happiest person in the world" arrived home sitting in the front passenger's seat. By definition that was my seat and I hardly ever ventured to the back seats. The following day we got the number plate, BG 424-16, which "the boys" attached to the car and made it legal.

Within weeks, I started checking the oil and water level of the engine and managing the tyre pressure. Almost every Sunday my father and I washed the car somewhere in the suburbs of Belgrade, where the water was publicly available. During those times I watched and learned how to start the engine and some other driving skills. By the age of 13, I convinced my father that the washed car should be drying outside

[18] The Evolution of Physics (pp. 158-159), Simon and Schuster, New York, New York, United States of America 1938

the puddle in which it was washed, so I was allowed to execute that "crucial manoeuvre". Father's agreement was the happiest moment in my entire life. Then, I learned that the bigger puddle I made while washing the car, the longer drive it would be. Hence, my driving distances were increasing meter-by meter, but in the "good direction"!

My father drove the car because somebody within family had to, but he took very little pleasure in doing it. To the contrary, for me that car was the centre of the universe. I learned, at the age of 14, how to change the engine oil, and what type of oil should be used in the cold winters and in the warm summers. Needless to say that replacing the water with antifreeze in October and draining the engine in spring were one of the most important assignments in my life.

All of my pocket money received for birthdays, New Year and other occasions, I spent buying models of cars that my family could not own. In that way many car types made by Ferrari, Porsche, Ford, Lancia, Alfa Romeo, Renault, Pontiac, Simca, Datsun, Toyota and other manufacturers started entering into my "bedroom garage" in scales of 1/18, 1/25 and 1/43.

Hands-on Experience

At the age of 14, after a lot of persuasion, initially of my parents, and then the owner of the Skoda Service and Repair shop in Belgrade, I managed to secure unpaid work as a car mechanic apprentice. At that time in Yugoslavia it was illegal to have anybody under the age of 18 in the work place. However, with full parental approval and the sympathetic views of the garage owner I spent the whole month working from 07.00 to 15.00, Monday to Saturday in a proper working garage. That was the best holiday I could imagine. The smell of petrol and oil, proper blue overalls, a huge collection of tools, inspection pit, diagnostic equipment, compressor, hydraulic trolley jacks and many other special tools and test equipment.

During these times I saw maintenance manuals for the first time in my life. I saw and used wiring diagrams, tyre construction and pressure charts. Regularly, I complained to my parents that none of these means of technical communication were ever mentioned in my classes in school, and yet they are essential for keeping machines in good working order.

At the end of each working day it was my job to collect the tools from the whole repair shop and put them on the wall at the marked places, and of course to report if any were missing. The prime reason for that was to ensure no tool has been forgotten in any engine bay or car that could cause problems to the owners and users.

From the money received for my 16th birthday I bought a hydrometer, a special instrument that measures the specific gravity of the electrolyte in a battery. I did this after reading somewhere that at the beginning of each winter the electrolyte specific gravity has to be above 1.2 g/ml. If that is not the case the battery needs to be purged and recharged, in order to be ready for sub-zero temperatures. When my first inspection of the battery was finished, I went home to report the state of it to the "family committee". Before I had a chance to say a word, my mother asked, "What have you done with your trousers?" When I looked down, to my horror, the trousers looked like a sieve – hundreds of small holes were covering them. Somehow, without knowing the nature of the electrolyte, I spilled it causing the total destruction of my trousers. By some miracle my hand and legs were not affected with this "beginner's error". However, when I said that I must go back to the car to clean the battery terminals and cover them with acid protective grease, otherwise the battery would be as bad as my trousers, my father said, "My son you cannot go out like this." I replied, "Why not?" Before anybody had a chance to say anything else, I disappeared.

Meeting in the Car Park at Belgrade Railway Station

In early 1960s there were quite a few cars in Belgrade, so when owners of the same type of car met at car parks they usually exchanged their experiences about the garages that serviced their cars. So it was that one day while my father was waiting for some visitors at the main railway station in Belgrade, a white Skoda 1000 MB parked next to him. Without hesitation the driver of the car approached my father and

wished him a good afternoon. Word by word they discovered that they were waiting for the same train, which was delayed for about 15 minutes.

Inevitably, their conversation reached the topic of servicing their Skodas. With very few garages that specialised in Skoda cars, they then discovered that they were using the services of the same garage. As both of them were very satisfied with the work done this topic was exhausted very quickly. Then my father was asked "When were you there last time?" "Several months ago," he replied. "Well, I would advise you to go there before the end of July." Surprised, my father asked, "Why before the end of July?" "Well, you must go there and see a very young boy who is working there as volunteer during the month of July. During the academic year he was attending the school, but during the July, with permission of his parents, he is helping at the garage to learn more about repairing Skodas, as his special interest. A few days ago I was there and observed him helping on a 20,000 km service on my car. I have never seen anybody enjoying so much doing mundane work like 'criss-crossing' wheels, changing the oil, spark plugs, contact breakers and other consumable parts. It seemed to me that his feet did not touch the ground. The enthusiasm and energy for what he was doing was really impressive. His parents must be the happiest people in the world."

Totally speechless, but proud, my father listened to this praise about his son. Then he said, "It is my son, we could not stop him doing it. Every morning he gets up at 05:45, by himself, has the breakfast prepared by his beloved nana, with a cup of cocoa and leaves at 06:15, in order to catch the bus at 06:19, to arrive at the garage a few minutes before opening hours at 07:00. Normally, he stays there until 15:00, but if there is any extra work to be completed for the day, nothing will stop him staying until the work is done."

Over the years my competence was growing rapidly. Due to my determination to learn: how the car works, what to do in order to keep it working and what to do when it fails to work. By the final year of my voluntary apprenticeship I had learned to perform rather complex tasks. I was confidently: adjusting clutch pedals; clearance of engine valves; contact breakers; spark plugs; adjusting the mixture of the fuel in the air in the carburettor and a few other tasks. All of that I learned by carefully observing what the other mechanics in the garage were doing. There was no book or any written material that I had ever seen that explained these activities. In the service books, the Skoda car producer clearly explained which maintenance tasks should be done at what frequency, but of course not how they should be done. It was expected the general public would take their cars to authorised garages for servicing and repairs.

During daily rides in public transport, to and from the garage, I entertained myself by addressing the following types of questions:

- Who and how do they determine the frequency and the content of inspections and servicing tasks?
- How all of that is coordinated across all parts of the car that are so different from each other?
- Do designers design the car and then while they are testing them decide the frequencies of adjustments, inspections and servicing or do they decide that before and then design it to those requirements?

Grand Prix Bedroom

Cars of all shapes, types, colours and usage were the focus of my life. However, racing and rally cars were closest to my heart. That was clearly manifested through the decoration of my bedroom. Wallpapers were never changed, as there was not a single square inch on any wall where pictures of cars and drivers were not covering it. They were: Graham Hill, Jack Braham, Jim Clark, Johan Rindt, Jo Siffert, Jackie Stuart, Clay Regazzoni, John Surtees, Mario Andretti and other drivers of that era.

I loved cars as the entity that made me happy in any shape, form or size. All cars are equally beautiful and attractive, without contradiction, from my point of view. Hence, without any particular order, F1 cars constructed by teams like Lotus, Ferrari, Honda, McLaren, Matra, March, Cooper, Brabham, Surtees, BRM and others were displayed on the walls of my bedroom. Most of these pictures came from Autosprint, the main Italian Journal for motorsport. In school I learned Russian as a foreign language, but my love for racing made me start learning Italian at evening classes.

Apart from a bed and a desk, in my room the biggest piece of furniture was a huge display cabinet, where I proudly showed my prized possessions: models of rally and racing cars. To the big surprise of my mother I even dusted the cars inside the cabinet, but hardly ever picked up my socks from the floor, somehow those things were outside of my life. Needless to say the boundless love of my grandmother Katarina, contributed to this type of behaviour.

The Red Notebook of F1 Failures

While the whole world was watching and following the race winner, I was collecting the data about those that did not finished, as many of them were victims of failures of different parts of the car, pit mechanics errors and other causes that prevented drivers crossing the finish line. I liked mathematics, and doing some maths on F1 races was the best thing to do on Mondays after the races, something that I still do today. In fact I looked at the data for days and tried to envisage what really cased failures like: oil; suspension; brakes; engine; out of fuel; water pump; cv-joint electrical and similar words used by newspapers and auto sport journals when they reported the outcomes of the races.

Running out of fuel, use to bother me for months! It is clear that the engine cannot run without fuel, but there are many reasons why the fuel was not available to the engine. For example, the race engineer did not calculate accurately the amount of fuel required to complete the race. Of course, it is always possible to put more fuel in, but then that extra fuel becomes an unnecessary load that negatively affects the performance of the car. The other option is that the race engineer calculated the correct amount of fuel but the mechanics failed to put in the amount required. Furthermore, it could happen that all parties, the race engineer and the mechanics have done their job correctly, but there was a fuel leak somewhere in the fuel system. Well, just stating “fuel system” as a cause of failure is such an all-encompassing expression saying very little about the real cause. Did the error originate in the manufacture of the fuel tank, or a missing washer somewhere in the fuel line, or a “pinched” rubber seal during the pipe replacement cause the leak? I had many questions, each technically and physically, based on my limited knowledge of car maintenance. Was the failure of a fuel pump, carburettors, fuel filter or any other part the cause of the event that was reported in the newspapers as “out of fuel”?

To deal with the phenomena that prevented racing cars and their drivers from crossing the finish line, I kept records of all failures of all F1 races, to do some statistics and write possible reasons for those events. I named it “Red Notebook of F1 Failures”. The book became my prized possession and was never far from me. It went with me on summer holidays, to cover the F1 races that took place in August, usually Austrian, Hungarian or German GP, and to help me during the long summer nights, which were very hot and full of “cheerful mosquitoes”, which regretfully never failed to find me.

The Red Notebook of F1 Failures was full of simple ratios, between the number of cars that finish the race and those that started. It was followed by the further classifications of those that did not finish, into following three categories:

- “Team” causes, that included all the failures of the cars, pit stop errors and from similar.
- “Driver” causes mainly covering spins, accidents, and similar actions.
- “Other” causes that included events like race stopped due to bad weather and similar events that could not be attributed to the first two categories.

Pages and pages of tables and graphs are in my book, all of which were free drawn by me, constituting my world, science, pleasure, fun, focus and enjoyment.

Monaco Grand Prix

Growing up in the Socialist Republic of Yugoslavia, my favourite annual event of the global significance was the Monaco Grand Prix. It is a Formula1 motor race that is held each year on the Circuit de Monaco since 1929. This event is widely considered to be one of the most important and prestigious automobile races in the world, alongside the Indianapolis 500, and the 24 Hour Le Mans. The circuit has been called “an exceptional location of glamour and prestige” as the race is held on a narrow course laid out in the streets of Monte Carlo, with many elevation changes and tight corners as well as a long tunnel, making it one of the most demanding tracks in the Formula1 calendar.

Watching the world of glamour and motorsport on the small black and white TV screen was a source of enormous pleasure for me. The beauty of Monte Carlo marina, filled with yachts and beautiful ladies, thousands of spectators scattered along the streets, the legendary tunnel through which cars go at full throttle, and the magic sound of racing engines open to view.

For me, watching each lap, following overtaking, accidents and failures, on sunny or extremely wet tracks were sources of huge enjoyment. The whole event was magic for me, as I dreamed of going there sometime in the future, of course, as a driver of those beautiful cars. It was a source of my motivation to study physics and maths, as without good science based knowledge about racing cars there is no chance of being part of that community, in my view!

Races were always exciting irrespective of the weather, the winning team or the driver. It was two hours of pure adrenaline, which came to my life with annual frequency. However, the culmination of the day was the award of the Trophy to the winning driver by Her Royal Highness Grace of Monaco. The beauty, elegance and always-present smile made her my dream Princess, forever. The only other female who could come anywhere near her, was the actress Audrey Hepburn. Torn between these two global celebrities, I enjoyed my life by regularly watching the F1 races and analysing the failures that prevented the drivers from crossing the finish line, as somehow I had become intrigued with the challenge of preventing this happening.

Finally, Dream Comes True

From the age of thirteen, when I started moving my father's car a few metres up or down from the place we washed it. I continued driving whenever we visited my grandmother, who lived in a rather isolated village on mountain Zlatibor, 200 km south of Belgrade, far away from the main roads and any traffic. That was my testing ground where I practiced driving and the skills of driving slowly, which according to many is more difficult than driving fast. Occasionally these visits would be during the winters, when there were lots of snow and ice on these off road tracks, which were challenging even for my father. With a bit of fatherly pride, he always stopped when we left the main road and let me drive the last few kilometres through woodlands to granny's house. The same happened when we were going home.

For about 4 years my only dream was to become 18 years old and to pass my driving test. Time passes rather slowly when you are a teenager, so I channelled my love for driving towards enlarging the collection of car models and spending as much time as possible working on real cars.

The family Knezevic lived in a skyscraper containing 52 flats, out of which at least 30 possessed a car. Hence, it was an amateur mechanics paradise. I was changing oil for half the building before the summer or winter season. I proudly used my battery charger and hydroscope to deal with ignition systems problems on my neighbours' cars, during the frozen winter months. Occasionally my parents were not that happy with my generosity towards our neighbours who were now relaying on me, but I always defended myself, as it was my pleasure and fun. Also, helping my neighbours I had the opportunity to learn on other cars that were designed and repaired differently from my father's Skoda. Hence, I had access to Fiat 1100, 1300, 124 and 125, Zastava 750 and 850, NSU 1000, 1200, Wartburg 1000, Volkswagen Beetle and a few other makes.

A few weeks before my 18th birthday, I took a double lesson with a qualified driving instructor to check my skills and to make a plan for the rest of the practicing. At the end of the lesson the instructor told me that I was ready to book the test, as he had nothing else to teach me. The rest is history.

On my first solo drive I took my beloved nana to visit her friend, who lived on the other side of Belgrade, whose health conditions prevented her going out. That was my way to say a huge thank you for everything that she had done for me over the last 18 years.

To drive more and more, during the school holiday times, I used to get up at 06:00, and drive my parents to work in the morning and picked up my mother in the afternoon. Every Sunday, at noon, I would go to pick up my grand aunt Lija and bring her to our flat for lunch. I never said no to any demand from anybody, which involved driving, at any time of the day or night.

I was one of the very first pupils in my class who possessed a driving licence. Predictably, girls from the school would occasionally ask me to drive them to meet their boyfriends or to pick them up after they missed the last public bus! Of course, I did it with great pleasure, as I enjoyed both their company and the driving.

Monte Carlo Rally

As a "realistic dreamer" with a driving licence, my attention was gradually moving from F1 cars to rally cars, which are in all respects much more accessible to people like me. So, I started attending a few opening or closing stages of some car rallies that took place around Belgrade and the nearby mountain Avala, which is the closest place where the speed trials were taking place. I loved the dynamics of the competition, variability of the road conditions through different stages, noise of the engines, and the diversity of skills demanded from the driver and co-driver. In F1, there are so many people doing their extremely specialised jobs, and all that happening within two hours of going around the same circuit. In rallying, each kilometre of the competition is different, spread over thousands of kilometres of day and night driving, with continuous map reading, self-planning for refuelling, maintenance, food, drinking, toilets and other actions!

As an award for the successful completion of my secondary school education, my mother bought me a book about the Monte Carlo Rally. Unlike books written by Dickens, Hemingway, Tolstoy and similar that stayed unopened for months and years, this one hardly ever left my hands. I learned that from its inception in 1911, by Prince Albert I, this rally was a proving ground for the competition under difficult and demanding conditions. It was an important means of testing the latest improvements and innovations to automobiles. Winning the rally gave the car type a great deal of credibility and publicity. This annual rallying event was organised by the Automobile Club de Monaco. Yes, the same one that runs Monaco Grand Prix for the F1 cars. In the late 1960s competitors would set off from all four corners of Europe, like: Stockholm; Paris; Glasgow; Lisbon; Frankfurt; Warsaw and Athens to "Rally" towards the final competition stages around the frozen hills of Monaco to determine the winner and celebrate the end of a unique event. Typically, each year the rally would attract around 150 crews, some of which would represents the world leading car manufacturers like: Ford, Lancia, Porsche, Renault, British Leyland, Simca, Peugeot, Saab and so forth, whereas other crews consisted of rally enthusiasts which were able to put together the necessary resources to participate. Consequently, legendary rally drivers like: Henri Toivonen, Ari Vatanen, Walter Röhrl, Bernard Darniche, Jean-Pierre Nicolas, Sandro Munari, Jean-Claude Andruet, Rauno Aaltonen, Pauli Toivonen, Timo Mäkinen, Paddy Hopkirk, Erik Carlsson and others found their place on my bedroom walls.

From the same book I learned that the Royal couple welcomes the competitors at the finish line to congratulate the winner and present the trophies. After the sensational victory of 1964 Paddy Hopkirk and Henry Liddon, in the Mini, Paddy said, "When I received the trophy from Prince Rainier and Princess Grace, I was dumbstruck. I could barely find the words to speak because Princess Grace was such a big star at the time."[19]

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[19] http://www.mirror.co.uk/news/real-life-stories/paddy-hopkirk-won-monte-carlo-3039361 (3.5.2017)

Part 2: Quest for Crossing the Finish Line Knowledge

"The principal goal of education is to create individuals who are capable of doing new things, not simply of repeating what other generations have done." Jean Piaget[20]

Since the smell of fuel attracted me, from the time I was in my mother's womb, and in all subsequent years, I enjoyed nothing more than driving, repairing, cleaning or just looking at cars in motion on the road or underneath from an inspection pit. Hence, to nobody's surprise, during the interview for compulsory military service in the Yugoslavian National Army, I managed to convince the Military Authorities to send me to the transportation division, which was as far away as possible from the guns I hated and close to the motor vehicles I adored.

A few days before going to Military service, I said a very emotional goodbye to my "hand-made" Z750. During the last three years "we" visited many places in Europe, participated in 5 rallies, travelled daily to the University and facilitated the kissing of a few girls, of course, only while stationary! From the money obtained, I bought an accordion for my father, who always wished to have one and a substantial golden chain tor my mother, as a sign of appreciation for everything that they had done for me during almost 24 years of my life.

I spent a year at the School for Reserve Traffic Officers in Titograd, Montenegro, where I learned how to drive heavy goods vehicles. Driving lessons on the dusty and deserted fields around Titograd were the brightest moments of my military career. It was the closest that I ever came to the "Safari Rally", the event I had been dreaming about participating in and still do! Even more, during those months I understood the inevitability of equipment failures and the importance of the maintenance management process that deals with them, together with the logistics support function that provides all necessary resources for repairing the failed systems. I found a lot of similarities between preparing a car for a rally and preparing a military vehicle for a mission.

In summary, I learnt how to drive heavy goods vehicles during the first six months of military service and taught the theoretical principles of the workings of motor vehicles to the new generation of reserve officers, during the remaining six months.

On the morning of the 5th February 1978, I shaved for the last time and returned to civilian life within a few hours. After the daylong train journey to Belgrade, I was met at the railway station by my parents, the rest of the family and friends were waiting at home, and the welcoming party had already started. My parents took me towards a brand new Skoda 120 LS, which I had never seen before, and while my father was giving me the keys of the car, my mother with tears in her eyes said, "This is our present to you, as you have done us proud all your life." Totally overwhelmed by this "huge present" speechless, I kissed both of them and started the engine of my new car.

While re-acclimatising to "normal" life and looking for my first job, I published my first scientific paper in a professional Journal[21], which was based on the research preformed for my Graduation Dissertation.

To make up for the "lost time" in military service, I spent the whole month of July driving and camping in my beloved Italy, with my primary school friend Mirjana, now a piano teacher, and some of her friends. During that time we got to know every single village and place on the circular train line "Circumvesuviana Napoli-Sorrento", visiting places like Torre del Greco, Pompeii, Vesuvius, Herculaneum, Torre Annunziata, and the island of Capri.

At the beginning of August I started looking for my first job and actively thinking about the continuation of my postgraduate studies.

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[20] Jean Piaget (1896-1980), a Swiss clinical psychologist known for his pioneering work in child development. Piaget's theory of cognitive development and epistemological view are together called "genetic epistemology"

[21] Knezevic, J**., "**A Contribution to Testing Grapho-Analytical Method for Determining Acceleration Time of Passenger Cars", Journal `TEHNIKA Masinstvo', No.10 pp. 10-13, Belgrade, Yugoslavia, 1978.

The Industrial Experience

The first job I applied for was at the GOSA Institute[22] in Belgrade. Within two weeks I had an interview, medical check and a job offer. My parents were extremely happy that I had got a job with one of the biggest companies in Yugoslavia. Especially as it was the only job I had applied for, thus far!

I started my working career as a development engineer in September 1978, in Belgrade. Whilst leaving for work, for the first time, on the doorstep of our flat, my parents wished me a successful career, and my mother added that the "world is ready to be changed". I adapted very easily to the working hours, from 07:00 to 15:00, and to wearing a white shirt and tie daily.

However, I still had the burning desire to learn the "scientific way" of understanding the failures of machines that I had experienced and the management processes that should be applied to deal with them in the best way possible.

Postgraduate Ambitions

In order to get permission and support from my employer, I volunteered to give a research seminar to colleagues about my postgraduate ambitions. The idea was well received and the date was set for my presentation. I addressed about 10 colleagues, with degrees in engineering, economics, management, material science, mining, mathematics and physics, with the following words:

"As you all know I recently completed my Military Service. During those, rather long, 12 months I spent in isolation from the "normal" world, I thought frequently about my university studies. Those thoughts helped me a lot while I was going through all the exercises, drills and routines of military life. Although I joined you recently, by now everybody knows that I have a huge love for machines, irrespective of whether they are pumps, generators, engines, compressors, cars, airplanes or any other entities. Today, I see machines as a set of components that perform their designated functions by means of their mutual interactions. Thus, the common characteristic among all machines is their ability to do something. Consequently, functionality is the most important characteristic of any machine, which is quantified through their performance characteristics, like speed, capacity and others. Hence, the whole purpose of engineering is to design them in accordance with the specifications. Translating it into simplified language, it means that a kettle, for example, is a machine that is able to satisfy a need for raising the temperature of the given amount of water to the given temperature, within a given interval of time and then cutting off the mains supply.

A few months ago I started thinking about the following: if they all exist to perform a function is there any scientific principle that enables them all to do so? Thus, today I wish to share, briefly, my current thoughts on that self-imposed question.

Based on all I have learnt so far, it seems to me that the main scientific principle that "drives" all machines to perform their designated functions is the principle of conservation of energy, which explains what happens to the energy when used. Despite the fact that this covers the functionality of all machines, it is really simple. It says that the amount of energy obtained from the machine is equal to the amount of energy put into it in the first place. As you very well know, classical mechanics distinguishes between potential energy, which is a function of the position of an object, and kinetic energy, which is a function of its movement. For example, there is energy that is stored in a spring, the heat energy in a petrol engine or the electrical energy stored in an electric motor. Hence, when a machine transmits force that is used to deliver a function, it can only deliver the same amount of energy as that put into it. In thermodynamics, one of the most challenging subjects I tackled at university, this principle is known as the law of conservation of energy and it governs all movements of all machines.

[22] Government of Serbia, in 1956, had established the Institute for education of the management personnel in economy, in Beograd, which 10 years later, became the Institute for organisation and automation of business "Organomatik. Then in 1978 it became the Institute GOSA working exclusively for factories in the GOSA Group. Its main task was to give a support to business functions production units, but, also, to be in the market competitively and professionally and be ready to react to changes.

For example, friction, which is the force between two sliding surfaces, converts energy to heat, but when everything is taken into account, no energy is created and none destroyed. If energy was to be destroyed as machines operate then, no matter how powerful those machines might be, they would slow down and eventually stop. At the same time, if the operations of machines create energy, then all machines would be getting faster and faster and the energy level would build-up to an unimaginable scale. Either way, the world would not have been as it is.

I am not sure if all of you are very familiar with thermodynamics, but as it is important to my future studies, please let me share my current understanding of it, with you now. It is a systematic study of the relationship between heat, work, temperature and energy, which encompasses the general behaviour of physical systems in a condition of equilibrium. A central consideration of thermodynamics is that all physical systems exchange energy and material with their environment. Thus, eventually they will spontaneously reach a stable condition (equilibrium) that can be described by specifying their properties, such as pressure, temperature, or chemical composition. If the external constraints are changed, for example, if the system is allowed to expand, then these properties, generally speaking will change. Thus, thermodynamics attempts to describe mathematically these changes and to predict the equilibrium conditions of the system.

Initial research in thermodynamics started in the19th century, when the main interest was focused on the question of the efficiency of heating engines. In all machines of that type heat is converted into useful work, with an unavoidable and irreversible process of dissipation of useful energy. It means that all heat can never be converted to work. Now, comes the toughest part of thermodynamics. The key concept in understanding these transformations is not energy, but the human created concept named entropy[23]. The law of conservation of energy states that whenever energy is converted in one form from the other, the total quantity remains the same. However, the main interest of thermodynamics is the usefulness of energy. Roughly speaking, energy of "ordered" things is useful, whereas the energy of "disordered" things cannot be harnessed to do work. For example, the energy stored in an "ordered" battery is useful, whereas the energy from the "disordered" fire that dissipated into the environment is effectively lost. Now, the real "killer" statement comes, entropy provides a measure of the degree of usefulness of energy of "disordered" systems. This means the higher the disorder the higher the entropy. When the entropy of a system reaches maximum, no further exchange of energy is possible as the system is totally disordered. This condition of a system is named the equilibrium state. The second law of thermodynamics states, that in closed physical systems, entropy does not decrease. That is, if the system is initially in an ordered state (low-entropy state), spontaneously its condition will change towards a disordered state, finally reaching the state of maximum entropy.

Let me give you an example. If two pieces of metal, at different temperatures, are brought into thermal contact, the unbalanced temperature distribution of a system, which represents a partial ordering of the energy, rapidly decreases to a state of uniform temperature, as energy flows from the hotter to the colder place. Having achieved this state, the system is in equilibrium. The motion of a system towards an equilibrium state is an irreversible process.

This natural tendency towards an equilibrium state is so fundamental to physics that the great Albert Einstein defined the second law of thermodynamics with the following words: "It is *the only physical theory of universal content, which I am convinced that, within the framework of the applicability of its basic concepts will never be overthrown."*

Well, my dear colleagues after 12 challenging months spent in Military service, I have reached the state of the maximum entropy, and I am sure you too, during the last 20 minutes of my presentation. Hence, to change the current state, I have to bring extra energy to my system, which means I have to make the next move. I want to research the application of thermodynamics and other sciences, to the further understanding of the mechanisms through which the irreversible processes of conversions of mechanical, electrical, thermal, chemical, and other types of energy into each other generate failures of machines.

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[23] Rudolf Julius Emanuel Clausius, (1822-1888), a German physicist and mathematician, had noticed that a certain ratio was constant in reversible, or ideal, heat cycles. The ratio was heat exchanged to absolute temperature. In 1865 he decided that the conserved ratio must correspond to a real, physical quantity, and named it "entropy".

Then and only then, in my view, we engineers will be able to successfully manage the consequences of failures on the reliability and safety of machines, during their in-service life. Frankly speaking that was my main reason for going to study mechanical engineering 7 years ago, but nothing of that happened. Thus, I hope the second time I will be "luckier".

In summary, I have decided to enrol on the postgraduate studies in Reliability engineering, at the University of Belgrade. Most of you are aware that Professor Jovan Todorovic, from the Department of Engines and Motor vehicles, is the leading expert of this subject in Yugoslavia. Thank you very much for your time and I hope that the knowledge that I expect to gain will be beneficial to all of us at the department."

My presentation was well received by colleagues. The Head of our Division said that the GOSA Institute would support my ambitions for the postgraduate studies in all ways possible, but regretfully they would not be able to pay my University fee or any other associated expenses. Without "wife and kids", I was happy to support my quest for science based knowledge of failures of machines and their management through appropriate maintenance methods. I considered this step to be essential for understanding failure mechanisms, some of which I had had practical experienced during the few years of rallying and many others through the collection of related data from F1 Grand Prix races.

Postgraduate Studies in Mechanical Engineering

At the beginning of the 1978/79 academic year I applied for the postgraduate studies at the Faculty of Mechanical Engineering, at the University of Belgrade. However, my average mark, from the undergraduate studies, was not in the top five among those who applied that year and was advised to try again sometime in the future.

I accepted the rejection from the University of Belgrade I had, after all, spent much of the five years as an undergraduate rallying. Not to be deterred, I decided to apply to study at the Technical University of Kragujevac (the birth place of the body shell of my Z750). I was accepted by the Faculty of Mechanical Engineering, as a part-time postgraduate student.

During the academic year 1978/79 I drove to Kragujevac each weekend to attend postgraduate lectures, and from Monday to Friday I worked as a project engineer, at the GOSA Institute in Belgrade.

Becoming an Academic

After receiving six salaries from the GOSA Institute, without being asked to do any specific job, I decided to look for a new job. I said to my parents, "As the world cannot be changed by doing nothing, I have decided to look for a new job." The reactions of my parents were very different. My mother immediately supported my decision, while my father recommended caution, as a managerial position could be possible within the next two or three years, in GOSA itself. I was not prepared to sit and wait for somebody to leave the company, or retire, in order for me to be "promoted".

A few days later my father mentioned to his good friend, the Director of the College for Advanced Education of Metal Workers, within the University of Belgrade, that his son was looking for a job. I was invited for an exploratory interview and within no time I had become an academic. My first job was to run tutorials in mechanics (statics, kinematics and dynamics), for a group of 30-40 students.

The sudden change in career came as a surprise to me. I always considered myself as a "hands-on" person rather than a "bookworm" person. The transition to the academic world was challenging for me, as among many other things, the vast majority of students were older than me. However, I was highly motivated to help them, as most of them had left school a long time ago and had had some difficulties switching back to learning mode. I organised additional tutorials to help the "struggling" students to see the world through the eyes of scientists that communicate with the rest of the world through the language of mathematics.

As the lessons were delivered between 17:00 and 21:00, because the students were working in factories and production plants, from 06:00 to 14:00 hours, I had plenty of time to focus on my postgraduate studies.

Being associated with an academic institution, I was motivated to write technical and scientific papers and to share my knowledge with other colleagues by attending professional conferences and symposia.

Life Changing Event

In May 1979, during the International Symposium on "Science and Motor Vehicles", I met my supervisor from the undergraduate studies at the University of Belgrade, Professor Jovan Todorovic[24]. At the end of a brief walk, along the lake in Bled in Slovenia, he suggested that I should transfer to the University of Belgrade and continue postgraduate studies under his supervision.

This was more than I could have hoped for. After several months of extended administrative procedures, and a few extra trips to Kragujevac, I was accepted to join the second year of the postgraduate studies at the University of Belgrade, under the condition that I passed all the exams from the first year of studies there.

In summary, at the end of the move to Belgrade, I had progressed one year forward regarding the learning process of my post graduate studies, but several exams "backwards", as far as the University of Belgrade was concerned.

Return to the University of Belgrade

At the beginning of the academic year 1979/80 there were five exams from the first year of studies waiting for me to pass, which were related to the methods for scientific research, graph theory, matrices, statistical methods and a few other elements of advanced mathematics. I also attended six postgraduate courses specifically related to the advanced studies of different aspects of motor vehicles.[25] However, my main problem was that these courses were based on the direct application of the laws of thermodynamics, fluid mechanics, materials science, dynamics, etc. but they did not address the observed operational behaviour of motor vehicles, which includes failures, repairs, replacements, spares provisioning and similar activities. Although these laws are valid in their domains, they are not sufficient on their own to create reliable and cost effective engineering systems.

I passed all the exams from the first years of studies, required by the University of Belgrade. The most demanding was Computer Programming. The whole course was based on the FORTRAN IV programming language[26]. For me, who could not speak a single word of English, it was extremely demanding, as I had to memorise all the commands that were in English. Although I had never seen a computer, I was able to create the necessary algorithms and write code that theoretically speaking would be able to run on a mainframe computer. It was rather exciting and frustrating, at the same time. The excitement came from seeing a computer as a very powerful and fast calculation tool and the frustration was related to my own inability to understand the English Language commands.

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[24] Professor Jovan Todorovic, was born in Belgrade in 1932, He was educated in Belgrade, where he graduated from the Faculty of Mechanical engineering in 1957. After several jobs in industry where he was gaining experience regarding the system effectiveness, he returned to the Faculty of Mechanical Engineering where he defended the Doctoral Dissertation in Reliability of Motor Vehicles and became a full Professor in 1974. Professor Todorovic co-authored the book "Effectiveness of Technical Systems", Naucna Knjiga, Belgrade (3 reprints, till 1994). He also authored the very first book in maintenance engineering in 1993 (Engineering Maintenance of Technical Systems, published by Yugoslav Society of Motor Vehicles). During his academic career professor Todorovic supervised hundreds of postgraduate students, published numerous books, chaired and attending numerous European Conferences, retired from the University in 1997, but continued to be very active in research and publishing. Professor Todorovic died 1 month after reading and approving all references to him made by me in this book.

[25] System Reliability, Methods for Testing Motor Vehicles, Stability and Steerability of Motor Vehicles, Maintenance Theory and Methods, Technological Aspect of Maintenance Systems, Motor Vehicles Control Systems

[26] One of the oldest and most used programming languages, the FORTRAN was developed by a team of programmers at IBM and was first published in 1957. The name FORTRAN is an acronym for FORmula TRANslation, because it was designed to allow easy translation of math formulas into code.

Reliability Theory

Professor Todorovic was the leading expert in Reliability Theory in Yugoslavia and very well respected within the larger European Community of researchers regarding the testing of motor vehicles. It goes without saying, I felt extremely fortunate to be taught Reliability Theory by him.

From the outset of the course Professor Todorovic emphasised that engineering systems are open systems, whose in-service life is under constant threat from internal and external impacting factors. As both types have stochastic characteristics the concept of reliability is defined through the probability that a system or a component thereof would operate without failure during a stated period of time. For me, the concept of reliability was an eye opener. It necessitated a departure from the deterministic engineering methods and formulas, to embrace probabilistic methods and formulas, which were totally non-existent during the 5 years of engineering studies just completed and over 40 exams that I passed.

Thanks to Professor Todorovic, who had introduced this course to the Faculty of Mechanical Engineering only a few years earlier, I learned about this new concept of addressing the behaviour of technical systems. Although it was something new that I had to learn and conquer analytically, it made perfect sense to me, physically. One of the main attractions of rallying is the continuous uncertainty of crossing the finish line. Hence, the most memorable moment in my whole life, and still is, took place on the 4th of April 1976, when the uncertainty of crossing the finish line, lasted for 669 km of continuous driving, and was "converted" into a certainty at the instant of time when we physically crossed the finish line at the Belgrade Fair ground.

While studying I contacted Vladimir Zeljkovic, a young officer who was sent to the University of Arizona to study reliability engineering under the supervision of Professor Kececioglu. Vladimir brought his lecture notes and a few books for me to borrow. However, to my huge disappointment, I could not make any use of them, as they were written in English. At the end of our meeting he said that reliability engineering was an extremely important new discipline, heavily based on probabilistic mathematics, and it was not that easy for mechanical engineers to switch to that type of thinking. He added that the Department of Defence in the USA was actively supporting reliability studies there.

Maintenance Theory and Methods

This was another course taught by Professor Todorovic to the Master's students in the Department for Motor Vehicles. I badly wanted to learn something "scientific" about maintenance, which I had practised under the directions of car mechanics and my own intuition for over a decade. Academically, maintenance has been perceived as a set of all activities performed to restore or retain a system in the functional condition. Accordingly, all maintenance activities could be classified into the following three categories:

- Corrective maintenance task: a set of activities that are performed with the intention of restoring the functionality of the system, after the loss of function, performance or both.
- Preventive maintenance task: a set of activities that are performed to reduce the probability of the failure of the system. Common preventive maintenance tasks are replacements, renewal, overhaul and similar. It is necessary to stress that these tasks are performed, at fixed intervals of time, regardless of the real condition of the system.
- Conditional maintenance task: a set of activities performed to gain insight into the condition of the system to determine further courses of maintenance needs.

Several mathematical models that enable the selection of the most appropriate maintenance policy were introduced in this course and illustrated with numerical examples.

I was extremely pleased with this course, as it showed me how maintenance was approached from a scientific point of view. It was not a course that taught me how to perform a maintenance task, but how to manage maintenance tasks to improve the in-service reliability and effectiveness of engineering systems. Although it was a course at the Department for Motor Vehicles, it was very generic and applicable to all engineering systems.

Old Habits Die Hard, African Adventure

I had not taken part in a rally for almost four years and I was badly missing the adrenaline-generating speed and need for rapid diagnostics and swift repair actions.

Since my teens, I had been helping my neighbours maintain and repair their cars. In the spring, 1980, one of those neighbours asked me if I would like to buy his Skoda, at a very reasonable price, as he had decided he no longer wanted to drive. I enjoyed the test drive so much that the same evening I asked my parents if they would object if I replaced, the two year old Skoda given to me by them, with the six year old Skoda of Mr Djuric. Although, my parents could not see the logic of my thinking, they said that I must make the ultimate decision, and that they would be happy either way.

Within days I sold my newer Skoda and bought my neighbour's older Skoda. Truth be known, I never liked new cars, as they are boringly reliable, they never cause any problems and on top of that they cost a lot of money, which could be spent on doing something exciting.

With the older car that could be exposed to tough and rough terrains and some money left from the sale of my newer car, I decided to go to North Africa during July and August. I put an advertisement in "Politika", to invite adventurers to join me in a circular journey around the Mediterranean Sea, from Belgrade to Belgrade via, Montenegro, Sicily, Tunisia, Algeria, Morocco, Spain, France and Italy. In the end, my primary school friend Mirjana "Mira" Djodjevic, a piano teacher, joined me as co-driver and an enthusiastic middle age couple, Zoran and Smilja Lazarevic, also decided to join us in their car, a Zastava 101.

I did very little in terms of preparing my new "old" Skoda for the journey. However, the same question kept coming back to my mind, as it did at the beginning of my 1974 trip to St Tropez, and at the start of every rally I had entered. It was that same old question "which spares should I take and, hence, what tools will I need?" Despite being in the second year of my postgraduate studies, I was no nearer to addressing this question. Fully aware of this fact, I made an agreement with my uncle Milenko Kasagic, the manager of the Skoda spare part shop, to take and pay for all the parts I wanted to take with me, but to get reimbursed for all the parts brought back.

The windows of both cars were covered by mosquito nets. Extra canisters for fuel and drinking water were added. We also took some food that could withstand high temperatures, a first aid kit, road maps, new air, fuel and oil filters, sleeping bags and many other items intended to make life in the car more "bearable". Obviously, none of the four "adventurers" were looking for the comfort of five star hotels, but we tried to include things that would make life easier and above all safer, in parts of the world of which none of us had any prior knowledge. I had about 30 kg of tools and consumables, like washers, screws, seals, electrical wires, steel wires, masking tape, plastic tubes, jubilee clips, electrical connectors, bulbs, hoses of different diameters, and everything else that I thought might be useful to us in the northern outskirts of the Sahara desert. One problem was no one outside of Eastern Europe had, at that time, heard of either Skoda or Zastava cars but that just added a bit of extra excitement and uncertainty to our journey. I was the only member of the team who was technically minded. The Lazarevic's were primary school teachers with a strong interest in art and music.

In the early morning of the 4th July 1980, the caravan of two cars left Belgrade with lots of apprehension, excitement and uncertainties, heading south to the port of Bar, in Montenegro, to catch an overnight car-ferry to the port of Bari, in Italy. While we were waiting for the ferry in Bar, I entertained my team with "war stories" regarding my participation in the Bar – Belgrade Rally in 1975! From Bari we headed towards the port of Reggio di Calabria to catch the ferry to Sicily, visiting cities of Taranto and Catanzaro. The 40-minute crossing to Messina was very pleasant and we had just enough time to drink an espresso.

The plan was to spend 3 days there visiting historical Roman cities and learning more about the island. We visited Taormina, Catania, Syracuse, Ragusa, Agrigento and Palermo. Finally we reached the port of Trapani to catch a 7-hour daylight crossing to Tunisia. On the ferry, we met many others intending to

explore North Africa, travelling in their own vehicles, without any fixed plans. The "camaraderie" became even stronger when we all had to fill in the Tunisian Government custom forms, which were printed in Arabic! After a good 3 hours of copying from each other and going rather slowly from one Border Official to the next, about 80 cars, off-road vehicles, camping vans and several motorbikes entered into Tunisia, all in good spirit, looking for new challenges and adventures. As often happens, common problems have the tendency to bring people together. So it was at the end of this lengthy border crossing procedure, all of the "adventurists" became like a united family. Everyone waited until the last vehicle had been cleared then we all sounded our horns in unison!

My group headed south towards Souse, to find a suitable space for our first African night. The following morning we entered into the part of Souse where all "foreign tourist" stay during their travel agency organised holidays, which was nothing else than a chain of luxury hotels and beaches with sun-beds and umbrellas, all along the Golfe de Hammamet. It was not for us so we headed 250 km southeast towards the old city of Sfax, on the shore of the Mediterranean Sea. The air temperature was over 40° C, but as it was very dry, it did not cause any problems to the Belgrade group. After a day spent by the sea, we got ready to start the African adventure. Both cars were going well, so I could focus fully on the scenery.

From Sfax we drove to Gabes, along the coastal P1 to join the P16 towards Qubili and Rabta, to start our first African challenge, a drive over the Chott el Djerid Lake. The bottom of the lake is between 10 and 25 meters below sea level. It is the largest saltpan of the Sahara Desert with a surface area of over 7,000 km^2. Daytime temperatures can reach over 50 °C. Annual rainfall is below 100 mm so in summer Chott el Djerid dries up, becomes driveable and numerous mirages occur, according to the guidebooks.

Mirjana and I would go first, and then Zoran and Smilja would follow us after 15-20 minutes gap, to let the "salt dust" settle. The lake is 45 km long and appeared to be an endless broken, white surface. I stopped, got out of the car and touched the ground, which looked like irregular shaped floor tiles made of rather large crystals of salt. I took a few pieces to take home as souvenirs. Mirjana and I looked at each other, and without a word we started our totally uncertain drive towards the village of Dguache, located on the other side of the Lake. Irrespective of the speed, the car was continuously shaking and vibrating. There were large cracks all over the surface and I was concerned not to damage the engine sump or gearbox. On numerous occasions Mirjana and I were convinced that there was a herd of camels running towards us. Needless to say, none of them came anywhere near our car, as they were never there. The whole excitement lasted approximately 90 minutes. After a good hour, the Zastava 101 arrived safely. United again, after the successful completion of our first "African Venture", the Belgrade adventurists drove straight to the nearby city of Tozeur on the road P3 that took us all the way to the Algerian Border.

Scenery, temperature, quality of the road, articles for purchase in local shops, people, crowds, friendliness of locals, were unchanging while we were driving through Sahara's cities of El Qued, Touggourt, Ougla, Ghardia, Laghout, El Bayadh, Bougtob, Mascara and to the Mediterranean city of Oran. It is the second most important city after the capital Algiers, due to its commercial, industrial, and cultural significance. If the citizens of Oran spoke French, nobody would have known that this was an African city. From there the two cars with their YU[27] plates headed towards Oujda, on the border with Morocco.

Again, the change of country changed nothing. We continued the African Adventure, business as usual, until we reached the small town of Guearcif, when my Skoda started making a noise like a Formula 1 car. The exhaust had developed a small crack on the weld between the silencer and the pipe that leads to the exhaust manifold. Truth be known, I liked the new "sporty" sound, but the rest of the team were worried about it. As all the shops and businesses were closed, I suggested we continue to Taza, about 60 km away.

About 20 km later, as darkness started settling, Mirjana and I heard a loud bang and our Skoda started making an unbearable noise. The Lazarevic's, who were only 100 meters behind, started frantically flashing their headlights. I stopped and switched off the engine immediately, as the noise was intolerable, even for me. When I was opened the door, Zoran was stood holding the Skoda's silencer in his hands. We looked at each other with a smile, and Zoran said, "At least we know now where we were going to spend one night!" The night was warm, the sky full of stars, the road dead silent, but I could not sleep. I was thinking about the broken exhaust. It would have been almost impossible to take a spare one, all the way

[27] YU was international auto registration mark for the country of Yugoslavia.

from Belgrade. Even more, it was unthinkable to carry welding equipment with me. Hence, feeling "rather less guilty" I decided to try to sleep.

The following morning, after breakfast, I detached the rest of the exhaust pipe. While we were trying to decide what to do next, out of nowhere, a rather "worn out" Peugeot 404 appeared and stopped. Two men dressed in typical African jellabah addressed us in French. Sadly nobody in our party could speak any French. I replied in Italian and word-by-word the conversation started. When I showed them the two parts of my exhaust, they smiled and gesticulated in the manner that they would take it with them to repair and bring it back. I looked at Mirjana, Smilja and Zoran, and their facial expressions were saying, "It is your car and you must decide." Being an optimist and well natured person, I handed them both pieces of the exhaust. With a smile they left towards Taza, at about 11:00, leaving us totally speechless, but I felt very hopeful.

Smilja started preparing the lunch, Zoran was looking for a bit of shade between the cars, Mirjana started writing post cards and I tried to catch up with my diary. None of us knew how long we would have to wait. We had food for about three days and water for maybe two, under heavily restricted use. The time was passing rather slowly and there were no signs of any movement on the road at all. Around 19:00, a ball of dust appeared on the road, far in the distance, but progressively getting closer and closer. Within a minute or two, I recognised the shape of the Peugeot 404 and started smiling at my fellow travellers. Our "saviours" had returned with the repaired exhaust, two loaves of freshly baked bread and several tomatoes, all of which they passed to me. Spontaneously and sincerely, I hugged them and said, "Merci beaucoup." which were the only two words I knew in French. When I offered money for the repair and food, they declined to accept it. Then I opened the luggage compartment of my Skoda, looked in it and took out a box containing seven light bulbs, a brand new set of five screwdrivers, a pack of eight 1.5 volt batteries, a few chocolates and a jar of raspberry jam. I put it all in a plastic pack and offered it to the "two strangers". After shaking hands with each member of my team, the "two strangers" departed with a broad smile. For me it was a victory of decency for the human race.

After installing and testing the exhaust, which sounded even quieter than before the crack, we spent the second night at the same place ready to continue the journey the next day.

After about 3 hours of driving we arrived at the historic city of Fes, where we spent the rest of that day and the following one, too. From there we visited the beautiful and historic city of Meknes, as we continued our journey towards Rabat, the capital city of Morocco and finally to Casablanca. As this was the most western point of our journey and we had driven over 4000 km, I decided to change the oil and oil filters of both cars and clean the fuel and air filters. After spending two days on the beach, we felt refreshed enough to start the journey back home, by driving north to Tangier and crossing the Mediterranean Sea by car ferry to Gibraltar. All four of us were sorry to leave Africa, as we had had the most memorable time there. We experienced many things for the first time in our lives, and each of us felt very proud that we made it in one piece back to Europe. The road forward was much less demanding on the cars, so the probability of completing the journey all the way back to Belgrade significantly increased.

Once we were back in Europe we agreed to make our separate ways back to Belgrade. Zoran and Smilja had a few friends in Spain they wanted to visit while we decided to take the pretty route and we headed towards Seville, Granada and Cordoba, where we really felt the culture, history and the beauty of southwest Spain. From there we visited Lorca, Murcia, Valencia, Tarragona and Barcelona to finally arrive at the French town of Perpignan, on the 1st August. The whole of France seemed to be on the move that day so we decided to do most of the driving through France during the nights and recover on the beaches of South France during the days. After bypassing Montpellier and Marseille, we finally arrived at St Tropez six years after my first visit there, with my friend Slavko, in my "hand-made" Z750.

After a few days of "holidaying" in the South of France we headed for home naturally via Monte Carlo, a place which will remain magical for me, at least as long as Formula 1 races are held there. I showed Mirjana the village of Breil-sur-Roya, a place in the French Alps, where my Z750 failed in 1974 and told her the whole story in detail, like it had happened only a month ago!

Within two days of leaving Monaco we arrived in Venice, via Turin and Milan. We both adored Venice, but for different reasons. For Mirjana, a piano teacher, it was a place where the history of music was

made, and for me it was a childhood's place of "magic", which never stopped being so exciting and welcoming. One night we watched Mozart's opera "Marriage of Figaro" in the theatre La Fenice, one of the most famous and renowned landmarks in the history of Italian theatre, of course standing in the top gallery.

The journey from Venice to Belgrade was almost non-existent, as all the time the memories of the Sahara roads, sand and their emptiness, were so strong in our minds. After 6 weeks of travelling and covering precisely 9645 km, we arrived home. My parents came to the suburb of Belgrade to welcome home the "African Adventurists" and to tell us the Lazarevic's had also arrived home safely a few days before and sent their regards to both of us.

For me, it was a totally new in-service experience. The environmental conditions, in which machines existed and operated, were hugely different from those I had ever experienced before. It was rather interesting to contemplate the question, "How many design engineers from the Skoda factory ever thought that their cars would be exposed to those conditions?" Also, I was concerned how the reliability methods and formulas presented by Professor Todorovic were able to address such conditions and facilitate the change in the design to accommodate them.

Scholarship for Reliability and Maintenance Studies in Moscow

During the two very demanding years of my post graduate study, I managed to navigate through all the educational "obstacles", successfully passed all of the exams and completed the research projects required before I was allowed to select the topic for my Master's Dissertation. To prepare for this final stage of studies, I decided to apply for a scholarship from the Serbian Ministry of Education to go to Moscow to study.

Arguably, the Soviet Union was not the leading nation in motor vehicle technology, but they were one of the top two space technology nations in the world. Also, some of the world's leading professors of probability theory, including Kolmogorov[28], Smirnov, Kozlov[29], Ushakov and Gnedenko[30], to name but a few, were in Moscow. Among them, Andrei Kolmogorov takes a special place, as his fundamental work, the original German monograph Grundbegrife der Wahrscheinlihkeitrechnung that appeared in the Ergebnisse Der Matamatik in 1933 is considered to be the birth of modern probability theory. It gives the basic concepts of probability theory, which had been considered to be quite a peculiar subject related to gambling, for a quite long time. In his view the theory of probability, as a mathematical discipline, had to be developed from axioms in exactly the same way as geometry and algebra. Given the basic axioms, all further expositions must follow logically, independent of the well-accepted meaning of these elements and their relations.

Probability theory is the area of mathematics with which, I as a graduate mechanical engineer, was the least familiar. I was never interested in spending time trying to understand the answers to questions like, "What is the probability of getting, say 9, by throwing two dice." Of course there is much more to it, but to a "petrol head" that was a brief summary of the topic of the study of probability.

However, having decided to study reliability and maintenance engineering related subjects, where all quantitative assessments are based on mathematical probability theory, it made sense to me to go there and learn it from the people who created a big "chunk" of the subject. Thus, it was my hope that studying probability theory in Moscow would enable me to investigate its applications to the quantification of the probabilities of failures of racing cars and other motorised systems in order to determine the appropriate maintenance actions which would increase the probability of crossing the finish line, metaphorically speaking.

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[28] Kolmogorov, A.M., Foundation of the Theory of Probability, second English edition, pp 84, AMS Chelsea publishing, Rhode Island, USA. 1950.
[29] Kozlov, B.A., Ushakov, I.A, Reliability Handbook, Holt, Renehart and Winston, New York, 1970
[30] Gnedenko, Kurs Teoriy Veroyatnosti, 5th edition, pp 400. Nauka, 1969, Moscow. USSR.

Also, the best books on reliability theory and engineering, published in English, had been translated into Russian, like Barlow[31], Kapur[32] and similar. Hence, it was a rare opportunity for me to have access to those books in the Libraries of Moscow University and even more to acquire some, as books were not very expensive to buy there, at that time.

At the beginning of my scientific career, I was very keen to learn, with ambitions to make some contribution to the existing body of knowledge, based on my experiences of repairing cars, from the age of 14, and from rallying them. Nevertheless, I was fully aware of the "mountain" that I had to climb in order to reach the current level of knowledge in reliability theory and its applications in Reliability Engineering and Maintenance Management, as none of these subjects had been taught to me during my undergraduate studies. I also had a huge desire to understand the "physical" side of these subjects that has not been that well addressed in the current literature, as the majority of the books were written by professors and members of staff from the departments of mathematics, statistics or operational research.

[31] Barlow. R.E., Proschan, F., Mathematical Theory of Reliability, John Willey & Sons, 1965.
[32] Kapur, K., Lamberson, L, Nadeznost i Proektirovanie System, pp 606, "Mir", Moscow, USSR, 1980.

Part 3: Crossing the Finish Line Conquering Knowledge

"A theory can be proved by experiment; but no path leads from experiment to the birth of a theory"
Albert Einstein

At the beginning of September 2004, for the first time since the age of 6, I found myself in the situation where, there was no beginning of the new academic year, new intake of students, welcoming speeches and the clear end to the summer holidays. The reason was very simple, as the Founder and the President of the MIRCE Akademy I had decided to discontinue the Master and Doctoral Diploma Programmes in System Operational Science! My conscience would not allow me to teach Programmes based on subject matter that had so clearly failed to identify or consider the observed in-service event, which was "crossing the starting line, twice"! Unquestionably, the aborted flight over the South Pole by Polly Vacher on the 5th of December 2003 was "the last nail in the coffin", as far as I was concerned, for the collection of non-cohesive subject matter, only loosely based on scientific principles and artificially shackled to the boundaries of the subject of interest. Although this situation was worrying for me, as a person fully responsible for "paying the bills" of the MIRCE Science and salaries of its employees, my professionalism, scientific credibility and personal morality would not permit anything to sway my decision regarding this. During those difficult days, the following words of my scientific hero, Richard Feynman, were constantly echoing in my head, "For a successful technology, reality must take precedence over public relations, for Nature cannot be fooled[33]."

As an academically educated individual: I was fully aware that scientific principles, concepts and laws expressed through the language of mathematics are the bedrock of any engineering creation. Natural sciences have achieved that status by providing accurate predictions for the resulting consequences of all designers' concepts, scenarios and "dreams".

As a qualified mechanical engineer: I was equally aware that the functionality performance of systems are the result of very complicated physical processes that are taking place inside them, like fuel combustion, electrolyses, heat exchange, expansion, contraction, etc. To learn the physical and chemical mechanisms of these processes I spent five years at Belgrade University in the Faculty of Mechanical Engineering.

As a rally driver: I was painfully aware that the most important in-service characteristic of all systems is the delivery of functionality in accordance with the scheduled timetables and ultimately crossing the finish line on time. However this type of performance is not addressed by functionality performance, in any way. In the simplest sense, will a car that is able to reach a maximum speed of, say 120 mph, going to cover, say 300 miles in 300 minutes, on a given road? How would the answer change if a driver is able or not able to do any maintenance? Assuming a driver is able to do maintenance, how would the answers change if water, fuel or oil pump is available as a spare part? The complexity of the questions increases rapidly and the ability of a human to use "common sense" or "gut-instinct" diminishes rapidly. Obviously, the questions could be asked in many other ways. For example:

- How many calendar hours are required to deliver, say 6,000 operational hours, under continuous usage, given that the operators are able, or not able to do maintenance, and the maintenance tasks could, or could not, be performed in situ, given that ……, given that …...?
- How many pieces will be made during the planned 6 months of continuous production, if a production line makes, say 50 pieces per hour, given that the maintenance department is working: one, two or three shifts?
- How many extra operational hours, during the 10 years of the design life, could be expected from a machine that needs 2 specific parts of the same type, working in parallel, to deliver the expected functionality, if it is designed with, say 4 of them working all the time, with or without maintenance checks and replacements of failed parts, given that …, or … given that … or given that,,.?

[33] Feynman, P.R., "Appendix F Personal observations on the reliability of the Shuttle", PCSSCA volume ii, pF53, "reality must take precedence over public relations" This is pointedly addressed to NASA, where the wishful thinking of pitching the safety of the shuttle led to public estimates of LOCV (loss of crew and vehicle) as 1 in 100,000 flights.

At the age of 52 (and ½), I reached a stage in my professional career when the theoretical knowledge gained through decades of academic education and experiential knowledge obtained through years of rallying and other types of driving on 5 continents, had to converge and create some new type of knowledge that would be able to provide accurate and insightful answers to the types of questions raised above, before the design of the "system" was finalised.

Scientific Response

"It is a miracle that curiosity survives formal education." A. Einstein

At the beginning of 2005, I started seeking the framework of the body of knowledge with which the totality of the solution for the quest for crossing the finish line, along with all other comparable human activities, could be properly addressed. Naturally, as a graduate mechanical engineer I started thinking about this challenge in terms of motion, which is one of the most fundamental concepts in science. I was thinking about the diverse types of motion, from cars to planets and beyond. However, all types of motion have something in common, which is the displacement of some objects in relation to others with respect to the passage of time. Hence, I spent a few months "refreshing my memory" about the fundamentals of motion in physics and looking at the concept of motion in quantum mechanics, in order to see whether my "scientific instinct" for addressing this challenge had any merit.

During decades of studying physics I "discovered" that when the concept of a particle is used, no specific image is connected to it, such as a car or a comet. It is enough to know that a particle is a specific object whose internal structure is of no particular interest, but which has mass, velocity, acceleration, momentum and a few others properties. The trajectory, or path, is yet another concept required in order to define the concept of the "motion of the particle". The trajectory of the motion of particle x(t) is said to be specified if at each instant of time t is possible to identify its coordinate x. To do this, it is necessary either to measure the coordinates x_i through time or to calculate them. I was fully aware that measurement is the concern of experimental science and calculation of theoretical science. I also knew that the latter is possible only if the laws of motion are described in the language of mathematics.

I recounted that a physical law defines a constant relation between the appropriate quantities that characterise the phenomenon, usually written by mathematical symbols in the form of equations. I was fully aware that each phenomenon is governed by a set of its own laws. There is one set for mechanics, fully defined by Newton's equations, and another set for electrodynamics, described by Maxwell's equations. Thus, it was evident that concepts, laws, formulas, methods etc. taken together, constitute an exact science. Although I knew what the new science should consist of, I did not know the properties of the new science that I was trying to conquer, in fact I did not even have a name for it!

I continued studying concepts of motion in science and "discovered" that as science progressed the mechanical way of describing motion became limiting. Although, it would have been possible, of course, to think of the case of a high-voltage transmission line that the wire is the "trajectory" of motion of the electric signals, such a mental picture would have no practical purpose, as the electromagnetic waves could not have been described as a liquid flowing through the wires. The true breakthrough began when scientists learned to trust the readings of instruments rather that to rely only on their perceptions. They used instruments to observe how substances behaved when an electric current was passed through the solution when dissolved, when substances were heated, illuminated and subjected to many other types of conditions. Scientists studied these phenomena; they did not merely observe them. They measured the temperature of bodies, the wavelength of light they emitted, and many other features that we are already familiar with. They recorded the results of their measurements in the form of numbers, which replaced direct sensations that scientists previously relied upon. Numbers were the only things that they came to trust when they began to study things that they could not physically perceive. Furnished with these numbers they began to seek relationships between them and started "imagining the world through the language of mathematics[34]" and thus formulating scientific laws.

[34] Robyn Arianrhod, Einstein's Heroes, pp 324, Icons Books, University of Queensland Press, 2003.

To learn how other scientists addressed this problem, I looked through scientific literature with hopes that existing knowledge could help me find the solutions for my quest for crossing the finish line. I found that the development of quantum theory was the best documented, perhaps because it is the most recent. I realised that defining the concept of motion in quantum mechanics was even harder and very different from the one adopted in classical mechanics. According to Ponomariev[35], the very day that this fact was established can be regarded as the birthday of modern quantum mechanics. Hence, while looking forward to this moment to come, regarding my "new science", I continued studying quantum mechanics and therein, for the first time in a few decades, I found myself actually learning something really new.

The revelation for me was the fact that many of the equations of classical mechanics, which describe how the motion of objects, at everyday sizes and speeds, ceased to be useful for the new phenomena. For a very long time I knew that the situation was paralleled to all of my attempts to use any aspects of classical mechanics to predict the in-service behaviour of systems. Moreover, in classical mechanics, objects exist in a specific place at a specific time. However, in quantum mechanics, objects instead exist in a "haze of probability"; which allows them to have a certain chance of being at point A, another chance of being at point B and so on, at the same time. I was extremely encouraged with this realisation, as I knew for sure that it is impossible for all the individual copies of the system considered, to be in exactly the same functionability state at any given instant of time. What I knew for sure was that, at any instant of time, the system considered will be in different functionability states, with probabilities determined by the in-service behaviour of the individual copies. Hence, my "only" problem was how to develop a method for predicting these probabilities for a given system, while it is still in the design office, rather than to hope that the observed in-service performance, decades later, will be acceptable to the user.

At this point of time, it became clear to me, that I was not developing a body of knowledge for measuring and statistically analysing the in-service performance of a system. I was developing a body of knowledge that must be able to predict the expected in-service performance of each feasible option of a future system, at the time when the design engineers or systems architects are using their knowledge, based on natural sciences, to make accurate predictions of the expected functionality performance. Only then would it be possible to "normalise" the expected in-service performance, for all feasible options, of the future system and through comparative analysis select the most favourable solution, regarding the combined impact of functionality and functionability performance, on the scale of the whole life. According to Jack, the intellectual effort required to achieve this would be comparable to the intellectual efforts required from other scientist to be awarded the Nobel Prize.

Origin of the Name MIRCE Science

At the end of numerous presentations related to my quest for this new body of knowledge, I was advised by participants and colleagues to name it, so that people could refer to it and recognise it. That was also a big challenge for me, as there was no obvious name in the English Language that could be used to define what I was trying to create. There were numerous disciplines that I was studying, with their own recognisable names, but there was nothing that integrated them and covered the whole spectrum of issues.

Through numerous discussions within the MIRCE Akademy, over several years, it became clear that the new body of knowledge should be named MIRCE Science. It was being developed at MIRCE Science Limited[36], which has intellectual property rights for research, publication, education, and training under the trademark name MIRCE™. Also, I realised that no other institution in the world could offer MIRCE Science related education and training services without approval from MIRCE Science Ltd. Of course, it would be up to us to make it an "essential" body of knowledge for scientists, analysts, engineers and managers involved in advanced research, design and management of the in-service behaviour of systems. While introducing MIRCE Science to a new group of people I usually point out that, "A new Ferrari car, can be obtained only from the Ferrari S.P.A., Via Abetone Inferiore, Maranello, Modena, Italy. Hence, it is impossible to learn and benefit from MIRCE Science from any institution other than the MIRCE Akademy, which is a division of MIRCE Science Limited." Ferrari's address has been in my head since

[35] [35] Ponomariev, L.I., The Quantum Dice, pp. 254, translated from the Russian by A.P. Repiev, Institute of Physics, London 1993, UK.

[36] Registered in England and Wales, Registration No. 3675242, Registered Office: Woodbury Park, Woodbury, Exeter, EX5 1JJ, United Kingdom.

the age of 10 and the “dream turned into reality” in July 1974 when I arrived there in my “hand-made” Z750! Simplistically speaking Ferrari S.P.A develops Ferraris so the MIRCE Akademy develops MIRCE Science, “tutto chiaro”, as Italians would say!
After settling on the name for this new discipline my thoughts were comforted by the fact that humans have named numerous planets, galaxies and cosmic constellations, whilst knowing very little about them! So surely, naming something MIRCE Science was not a big deal, in the great scheme of things! However, putting useful and irrefutable content “in it” was! This I knew very well, as the memories of promoting and demoting System Operational Science within the MIRCE Akademy still pained me. Of course that had nothing to do with its name; it was all to do with the inadequacy of its content, which was of my own making.

While working tirelessly on the content of MIRCE Science, I learned the definition of science, from my great friend and colleague Professor Arie Dubi. He said, “Science is any realm of human activity in which two conditions are fulfilled: 1.A systematic study of laws and rules that enables prediction of future behaviour of systems to be done; 2. Definition of ‘truth’ exists independent of the human beings.” [23] This definition of science helped me immensely, as it is the only one, known to me, where the scientific laws are combined with the rules that govern the future behaviour of the system considered are mentioned. Hence, that was the beginning of my new quest to scientifically consolidate my academic knowledge based on laws of natural sciences with my experiential knowledge based on in-service rules and regulations, made by humans. In considering this, I realised that these two fundamentally different entities could coexist in science, as they unquestionably had in my endeavours for crossing the finish line. Laws of natural science govern physical processes like: corrosion, fatigue, friction, radiation, embrittlement, depolymerisation and many others, whereas the human made rules govern the rallying procedures in my specific case, or generally speaking all operational, maintenance and support rules based on international and national standards, together with the specific organisational rules of the users.

Functionable System Type in MIRCE Science

I felt strongly that the first thing to be done, regarding MIRCE Science, was to make a clear distinction between the concepts of a system, as currently perceived by the systems engineering discipline and my “newly discovered entity”. The former was concerned with the functionality performance of a system (maximum speed, acceleration, fuel consumption, etc.), whereas that latter should be concerned with crossing the finish line, on time. Hence, in my view, there was a huge difference between the system Z750, as perceived by its manufacturer (Zavodi Crvena Zastava in Kragujevac in the mid 1960s) and the system Z750 as part of the Knezevic-Glumac-Team, driven, managed and financed by myself. The former existed in accordance with the laws of natural science only, whereas the latter “lived life” in accordance with, what I perceived to be, MIRCE Science (a combination of the physical laws and human rules). These rules were contained within the chosen policies and strategies that govern the operation, maintenance and support processes leading to crossing the finish line, on time. For example, a system Z750 with a spare fuel pump would generate a different trajectory of motion during the rally compared to a system Z750 with a spare water pump, as I had experienced almost three decades before. Consequently, I coined the name “functionable system type” as a generic name for a “set of mutually related components uniquely put together to perform at least one measurable function and the set of rules that govern its operational processes.”

I felt that the creation of the concept of a functionable system type was essential for the development of MIRCE Science. It made me realise that as far as the systems engineers at Zavodi Crvena Zastava were concerned, when they designed the Z750 decades ago, I was driving the one and only functional system type, namely a Z750. However, the system Z750 with a spare water pump is a different functionable system type from the system Z750 with a spare fuel pump, which is different from the system Z750 with a spare oil pump, as the chances of crossing the finish line are different for each of them, while competing on the same road, subjected to the same environmental conditions and competition rules.

At this stage in my research, I became “petrified” with the huge number of possible variables that would have to be defined in order to uniquely identify each functionable system type. However, all of these variables have to be taken into consideration, as each combination would have constituted a different functionable system type and consequently would have delivered a different operational performance.

The more I progressed with the research the more I was realising that Jack's "Nobel Prize Hint" was fully justified, if not even "a little understated".

Functionability States, Actions and Events in MIRCE Science

> *"Motion does not mean travel of the ball-type electron along some orbit around the nucleus. Motion is the change in the state of the system "atom" in time."* Werner Heisenberg

After several decades of observing and experiencing the in-service behaviour of functionable system types, I concluded that in MIRCE Science, from a functionability point of view, at any instant of calendar time a given functionable system type could be in one of the following two states:

- Positive Functionability State (PFS), a generic name for a state in which a functionable system type is able to deliver the expected measurable function(s),
- Negative Functionability State (NFS), a generic name for a state in which a functionable system type is unable to deliver the expected measurable function(s), resulting from any reason whatsoever.

The motion of a functionable system type through the functionability states, in the direction of time, is generated by functionability actions, which are classified as:

- Positive Functionability Action (PFA), a generic name for any natural process or human activity that compels a system to move to a PFS.
- Negative Functionability Action (NFA), a generic name for any natural process or human activity that compels a system to move to a NFS.

The motion of a functionable system type through the functionability states is manifested through the occurrences of functionability events, which are classified as:

- Positive Functionability Event (PFE), a generic name for any physically observable occurrence in time that signifies the transition of a functionable system type from a NFS to a PFS.
- Negative Functionability Event (NFE), a generic name for any physically observable occurrence in time that signifies the transition of a functionable system type from a PFS to a NFS.

Consequently, I started "conceptualising" MIRCE Science as the theory of the motion of a functionable system type through the functionability states resulting from any functionability actions whatsoever and the actions required to produce a functionability motion.

Functionability Performance in MIRCE Science

> *"In science one tries to tell people, in such a way as to be understood by everyone, something that no one ever knew before. But in poetry, it's the exact opposite."* Paul Dirac[37]

I was only too aware that numerous specialist engineering disciplines, like reliability, maintainability, supportability, testability and similar, that endeavoured to address specific characteristics of components or modules, had been in existence for over 50 years. However, I realised that despite the fact that all of these specialist disciplines have their own specifications and procedures there was nothing to "normalise" their interactions and express them in a quantitative manner reflecting the in-service performance of a system type. The ability to "normalise" would enable comparisons to be made between all the feasible

[37] Paul Dirac, 1902-1084, British quantum physicist, Nobel Prize recipient in 1933.

functionable system type solutions identified, and finally select the best compromise among the competing options.

My rallying past was still “haunting me”, regarding the impossibility of even address the question “Are the chances of crossing the finish line higher with spare: water, fuel or oil pump?” However, manufacturers of each pump are legally required to quote reliability, maintainability and supportability characteristics, at least in western defence and aerospace contracts. And then, “the penny dropped”, although the reliability, maintainability and supportability characteristics of all the parts are know, what was not known, at all, was how they would influence the chances of a rally car crossing the finish line, in my case, or how many flights to Cleveland would be completed “on time” during a year or a decade of operation, in Jack’s case, while it is still on the drawing board? Finally, I realised more clearly what had to be done, but the “only” question for me was how to do it?

My position was particularly challenging because the educational programmes and training courses, which I had been running at Exeter University, focused on those individual specialities. All of them were correct for those professionals who wished to specialise in one of these disciplines. However, now I was looking to the future research, education and training activities of the MIRCE Akademy, which by necessity had to refocus on “discovering” or “inventing” the quantifiable characteristics of the in-service performance of a functionable system type that are “physically” observable and could be calculated for each design alternative, for comparative purposes. In one word, the new characteristic(s) must reflect the ultimate “reason for existence of the functionable system type”. This was the fundamental, aspect of the research that I had to resolve.

While I was thinking hard about the all-encompassing characteristic(s) that could be used to quantify the ultimate “purpose of existence” of any functionable system type, I received a request, from a classmate, from the XIII Belgrade Classical Gymnasium, to write a contribution for a publication “Collection on Memories (1967-1971)” to celebrate the 40th Anniversary of our matriculation. The following weekend I started thinking what to write. I was hugely surprised how quickly those beautiful years of my life “came back”. Classmates, teachers, exams, sport’s days, annual excursions, first love, the Beatles, the Monaco F1 Grand Prix, the Wimbledon Men’s Final matches, and many more memories so vivid and clear you could almost touch them. Effortlessly, by the end of Sunday evening, I had completed my “memories” and emailed the 12 pages back to Belgrade.

However, during the following few weeks those happy memories continued coming to me. One of them was my final exam in physics, where the very first question was related to the concept and units of work in physics. While writing the memories, I immediately “saw” the page and every single word written in my notebook related to the definition of the work. With strange emotions I wrote the following words on the piece of paper, “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 “light bulb moment” for conceptualising my quest for crossing the finish line. It became crystal clear to me that the purpose of existence of every system that humans have ever created is to do something through time, as it is inconceivable to me that something would be specified, designed, produced and acquired by somebody in order for it to do nothing. Very quickly I realised that the “purpose of existence” of any system is to “do something through time”, which I named functionability work, to differentiate it from the well-know concept of work in physics Hence, functionability work is considered done when a system delivers a measurable function over an interval of time, in a similar way that classical physics, considers work done when an external force displaces an object over a distance.

Consequently, in MIRCE Science functionability work, as I conceptualised it, is classified as:

- 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]. In the Founder’s Lecture I referred to the relevant data related to the B747, with tail number N747PA (see Table 2.2). As a part of my hobby, or more accurately to say my “childhood

obsession", I have collected information about PFW done by every single driver in every single F1 race, since the first race on the 13th May 1950, Silverstone, England. The most fascinating example from my Red Notebook of F1 Failures is the remarkable achievement of Michael Schumacher, during the 2002 F1 season, when he had delivered PFW during each lap of each of each of the 17 Grand Prix races, something that has never been observed before or repeated since (at the time of writing this book).

- 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]. For the relevant data related to the Pam Am's Boeing 747 (see Table 2.3). Information of this type is impossible to deduce from any available functionality performance measures published by the Boeing Corporation, since unveiling this aircraft in 1969, to the best of my knowledge! Of course this situation is equally applicable to any other product made by the Boeing Corporation or any other functional systems that have ever existed.

To explain the concepts of positive and negative functionability work, I normally use the example of the 2003 Monaco Grand Prix race, for no particular reason, other than the fact it is my "life time" favourite F1 racetrack laid out in the city of Monte Carlo and La Condamine around the harbour of the principality of Monaco! The length of each lap is 3.337 km. Hence, the functionability work expected to be done, by each functional system type, in this case the entire F1 team, is for each of the two drivers to complete the full race distance, which is 78 laps.

The race winner is the F1 team whose driver crosses the finish line first, and that is the last lap of the race for all the teams. Table 3.1 shows the summary of that race, analysed in the MIRCE Science manner, where; Csec, represents the total calendar time of the race (measured in seconds), Psec represents the positive functionability work (racing on the track) done by the functionable system type (F1 team) and Nsec represents negative functionability work, (tyre changes and other necessary actions performed in the pit) done by the functionable system type (F1 team).

Finsh	No	Driver	Team	Laps	Csec	Psec	Nsec
1	3	Montoya, J.P	Williams-BMW	78	6139.010	6081.806	57.204
2	6	Räikkönen, K	Mclaren-Mercedes	78	6139.612	6081.504	58.108
3	1	Schumacher, M.	Ferrari	78	6140.730	6083.947	56.783
4	4	Schumacher, R.	Williams-BMW	78	6167.528	6109.376	58.152
5	8	Alonso, F	Renault	78	6175.261	6120.460	54.801
6	7	Trulli, J	Renault	78	6179.982	6124.681	55.301
7	5	Coulthard, D	Mclaren-Mercedes	78	6180.237	6124.489	55.748
8	2	Barrichello, R	Ferrari	78	6192.267	6134.766	57.501
9	21	da Matta, C	Toyota	77	6194.032	6136.210	57.822
10	11	Fisichella, G	Jordan-Ford	77	6194.001	6134.239	59.762
11	9	Heidfeld, N	Sauber Petronas	76	6195.211	6138.228	56.983
12	12	Firman, R	Jordan-Ford	76	6195.632	6134.794	60.838
13	20	Panis, O	Toyota	74	6195.761	6162.020	33.741
DNF	16	Villeneuve, J	BAR-Honda	63			
DNF	18	Wilson, J	Minardi-Coswort	29			
DNF	19	Verstappen, J	Minardi-Coswort	28			
DNF	14	Webber, M	Jaguar-Cosworth	16			
DNF	15	Pizzonia, A	Jaguar-Cosworth	10			
DNF	10	Frentzen, H.H.	Sauber Petronas	0			

Table 3.1: Positive and Negative Functionability Work done during the 2003 Monaco GP Race.

The pattern of the motion of a functionable system type through functionability states is determined by the sequence of occurrences of functionability events. Figure 3.1 shows the sequence of functionability events for a single functionable system of the type considered (it is an expansion of the functionability profile shown in Figure 2.1). Functionability work done corresponds to the cumulative time that a functionable system type spends in each functionability state. As this motion is in the direction of the time, it means that the magnitude of the positive and negative functionability work done are non-decreasing physical properties of functionable system types, and as such, they are representative measures of their functionability performance.

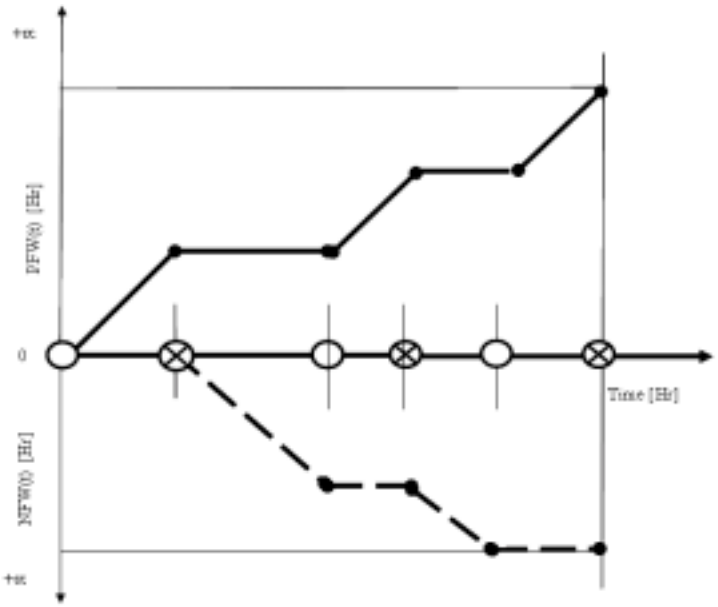

Figure 3.1: Positive and Negative Functionability Work Done
by a Single Hypothetical Functionable System Type

Although I was extremely happy with the "discovery" of the concept of functionability work, very quickly it became obvious to me that it was only a partial solution to the quest for crossing the finish line, as the physical resources related to the execution of functionability works, like material, personnel, spares, tools, equipment, facilities, energy and similar must be taken into account. As all of them have individual monetary values, it is logical to bring them all together under the single umbrella of functionability cost. Consequently, in MIRCE Science the concept of functionability cost, as I saw it, could be classified into following two types:

- Cost of Positive Work (CPW): a generic name for the physically measurable performance of a functionable system type determined by the monetary value of all the resources related to the delivery of positive functionability work, like operational personnel, consumable material, equipment, facilities, energy and similar. Generally speaking, as far as I was concerned, it encompassed all the costs related to delivery of the positive functionability work by the functionable system type during a given interval of calendar time *T*, denoted as ***CPW(T)***. It is equal to the sum of the following cost elements:
    - The Set Up Cost ($CPW_{set}(T)$): a generic name for the cost related to the provision of a new or modification of existing operational resources like equipment and tools needed for the system operation, additional training of operational personnel, modification of existing or construction of new operational facilities, and similar types of resources that have to be obtained prior to the introduction of the functionable system type into service.
    - The Fixed Cost of delivering positive work ($CPW_{fix}(T)$): a generic name for the cost related all expenditure that is not related to the amount of positive functionability work done. Typical examples are: insurance cost, health and safety issues, personnel training cost, licensing costs and so forth.
    - The Variable Cost of delivering positive work ($CPW_{var}(T)$): a generic name for the cost related to the resources consumed by the system while delivering positive functionability work.

Based on the above cost categories a generic expression for the total cost of delivering positive work during the stated period of calendar time *T*, measured in relevant Monetary Units [MU], could be expressed as follows:

$$CPW_S(T) = CPW_{set}(T) + CPW_{fix}(T) + CPW_{var}(T) \quad [MU] \qquad 3.1$$

I was fully aware that those cost categories are well understood by the accountancy departments of the airlines and other industries, but I was equally aware that these costs are rather unknown quantities to engineering design offices, as a student of mechanical engineering I had never been exposed to them. In summary, the cost of doing positive functionability work could be calculated for each functionable system type and consequently used as a measure of its functionability performance.

- Cost of Negative Work (CNW): a generic name for the physically measurable performance of a functionable system type determined by the monetary value of all the resources used by a functionable system type to perform the negative functionability work, like spare parts, qualified personnel, material, equipment, facilities, energy and similar. Thus, it encompassed all the costs related to performing the negative functionability work, performed on the functionable system type during a given interval of calendar time *T*, denoted as *CNW(T)*, and is equal to the sum of:
  - The Set Up Cost ($CNW_{set}(T)$): a generic name for the cost related to the provisioning of new or modification of existing maintenance resources. Typically, new equipment and tools for the maintenance of the system, additional training of maintenance personnel, modification of existing or construction of new maintenance facilities, and similar types of resources that have to be obtained prior to the introduction of the functionable system type into service.
  - The Fixed Cost of delivering negative work ($CNW_{fix}(T)$); a generic name for the cost related to all expenditure that is not related to the amount of the negative work done. Typical examples are insurance cost, health and safety related issues, personnel training cost, facilities rent, licensing costs, updating of technical information and so forth.
  - The Variable Cost of negative work ($CNW_{var}(T)$): a generic name for the cost related to the resources used while delivering negative functionability work. Hence, the cost of doing negative work is a measurable quantity for each functionable system considered.

Based on the above cost categories a generic expression for the total cost of delivering the negative functionability work during the stated period of calendar time *T*, in MIRCE Science is defined by the following expression:

$$CNW_S(T) = CNW_{set}(T) + CNW_{fix}(T) + CNW_{\text{var}}(T) \quad [MU] \qquad 3.2$$

The delivery of positive and negative functionability work through time uniquely determines the positive and negative functionability costs that correspond to the motion of a functionable system type through the functionability states. As this motion is in the direction of calendar time, it means that the magnitudes of the positive and negative functionability costs are non-decreasing measurable characteristics of the functionable system types, and as such they are "legitimate" measures of their overall functionability performance.

Although I was not that interested in finance and accountancy per se, I knew that the functionability cost categories are very well monitored and accounted for, by the operators and users. However, I was fully aware that the orders of magnitude of these costs are determined by the decisions made in the design office at the very early stages of the design process. Regretfully, there is a "life time difference" between the moments in time when the functionability costs are committed in the design office and the time when functionability costs are measured by the accountancy office of the users. This fact of life convinced me that the solution to the quest for crossing the finish line must enable the design office to compare all the feasible solutions regarding the new design in terms of the overall functionability cost and for the chosen solution to inform the user's accountancy office what the functionability cost is expected to be. This was far from the current industrial practices, known to me!

Plan for All Conquering Research

Having defined the quantitative measures of the functionability performance of a functionable system type, the time came to make a plan for the development of the all conquering body of knowledge that will enable accurate predictions to be made while functionable system types are being designed. My goal was to create a knowledge that would enable design teams to "see operational behaviour" of future functionable system types in quantitative form, for comparative purposes, as Jack needed during the development of the maintenance philosophy of B777 or at the beginning of each rally, in my case.

To proceed with the creation of MIRCE Science and justify Jack's belief that it deserves a Nobel Prize, I decided to subject the in-service behaviour of functionable system types to the proven methods of science and mathematics, to:

1. 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[38], and to determine the patterns of their behaviour in the direction of calendar time.

2. Scientifically understand the physical phenomena and human actions that govern the occurrences of functionability events[39] 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).

3. 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.

I was imagining that my research will finally generate a theoretical body of knowledge that comprises of mathematical equations and computational methods that enable predictions of functionability performance of a given functionability system to be done, at the design stage, driven by: the physical properties of functional systems, in-service constraints and given rules (related to the operational scenario, environmental conditions, maintenance policies, support strategy).

[38] 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.

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

Epilogue: Thanks Jack

> *"Dear Dr. Knezevic,*
> *Thank you for sending me this update on the recent Congress and your progress with the science of Mirce Mechanics. I am encouraged to know your important efforts continue and are supported by such a fine compliment of our industry colleagues. I am sorry I was not able to join you this year, as I was on leave from my work here at Boeing when the invitations to your event went out. Perhaps next year I will join you once again. I wanted to let you know that our mutual friend and colleague, 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 rehabilitation Hospital, but has made little real progress toward being himself again. I am sorry to write with this discouraging news, but I knew you would want to know. Warmest regards, from Seattle"*[40]

After receiving this extremely sad and disturbing information from Justin, I started thinking about the best course of action, regarding "my Chief Mechanic". Although good friends, Jack and I had not been in "daily" contacts, due to our frequent travels. Jack loved travelling, and since he retired the travels lasted longer and longer. Throughout his lifetime Jack visited all seven continents, travelled by all means of transport, adored and respected nature and loved observing polar bears. On numerous occasions I would ring his home, leave a message on the answering machine and a few weeks later, even months, Jack would send a few photos from his latest travel adventure, with a few words that described them, with a unique and very refreshing sense of humour.

The first thing that I did was to locate the hospital where Jack was. It was Seattle Medical Post Acute Care, from which website; I got the email address that enables contact with their patients. On the 25th June I sent the following email to Jack:

"Dear Jack
Thinking of you 24/7. I learned about your condition from Justin Hale last Friday. As you are my very best friend I would like to come and visit you soon. Hence, would you like me to come and when it will be the best?
Also, would it be possible to let me know the contact details of your sister or your nephew?
I know that you are fighter and I am sure you will win this battle too. Maintainability is all about making it to work, so I am sure will make yourself to be "as good as new" condition very soon. Please keep in touch as much as feasible.
With huge hug from your English friend."

After, a few days of uncertainty and expectations, I received the following reply from the Seattle Medical Post Acute Care:
"Hello, I spoke with Jack and he'd love a visit from you. He smiled when I brought your name up and was in a joking mood this morning. We do not have a room on sight for visitors but have hotels near. Please feel free to let us know how we can help. Here are the contacts:
George Yesian, Marketing & Admissions Director"

Within several hours of receiving a green light from Jack, I booked the flight for Seattle and started changing and altering my arrangements and duties scheduled for that week. On Sunday the 21st of July I

[40] Email that Justin Hale, a Honorary Fellow of the MIRCE Akademy, sent to me on 20 June 2013. He was one of the Keynote Speakers of the 1st World Congress of MIRCE Mechanics in May 2012. Justin, as a Regional Director, Product Marketing, Boeing Commercial Airplanes, talked about Maintainability in Design of B787, known as Dreamliner. I was extremely happy to welcome him to the MIRCE Akademy as after Jack's retirement I have been trying very hard to learn what is going on with my favourite job at my favourite aircraft company. (Personal Archive of Dr Knezevic)

boarded the United Airlines flight UA921, from London Heathrow to Washington DC, as I had done many times in the past, including the inaugural flight of "Jack's plane".
Hello Jack, as "Hi Jack" is a prohibited expression in Aviation

On Monday 22nd July, at 08:00 I arrived at Seattle Medical Post Acute Care. I was sent to room 216, which Jack shared with another patient. Jack welcomed me with a rather cheeky smile, typical of Jack when he wanted to make a point for something important. I hugged him and said a few words, but nothing was coming back from him. Then, I realised that due to his "injuries" he had lost the ability to speak in a natural way. It was a rather tense time for both of us, but the energy from the mutual happiness was stronger and we communicated without any words coming from Jack. After a while, I went to introduce myself to the Management and Medical team of the Hospital, as I wanted to learn more about Jack's medical condition. Very soon I realised that nobody among them knew who the "real" Jack was. I shared with Rachael Gerdis, Executive Director of the Centre and her close team, some of the documents about Jack's career that I brought with me, mainly what we have done together, during the last 16 years of collaboration. Rachel was so impressed that she immediately asked me for permission to photocopy all of those documents and put them in Jack's file, to enable all the medical staff who was working on different aspects of his health to learn more about his profession, achievements, hobbies and general personality, as that will help them to tailor the therapies for him.

I asked about Jack's ability to speak. The answer was more than welcome, as I was told that the speech therapist would come to Jack's room and insert the "communication device" in his breathing tube and he would be able to conduct a conversation on his own accord. Within no more than 10 minutes Jack and I were talking normally. Jack thanked me for coming and asked about Nigel Mansell, Lynn (my partner), Clive (the Director of operations of the MIRCE Akademy), Flying Lady, (Polly Vacher) and a few other people from Exeter. During this "barrage" of questions I could not believe how "sharp" Jack was and how easy our conversation was flowing, in comparison to the first few minutes. While we were talking, various members of medical and support staffs were coming in and out, taking different measurements from the instruments connected to Jack and taking measurements from his body, like sugar level and others.

Around noon, Jack gradually drifted into sleep, after almost 3 hours of very intense discussions with me, something that had not happen before, as all his sessions with a speech therapist lasted around 15 to 20 minutes. While Jack was deeply in sleep, I was sitting next to his bed and thinking that the person who was in charge of designing the "health care system" of many aircraft types during his career, now is kept in life exclusively by a machine, without any input from him. A model of B777 was on the bedside table, together with a helium balloon with a Happy Birthday message (Jack's 79th birthday was 19 days ago, on the 3rd July).

After Jack woke up, he looked in my direction and was very happy to see me there still. Just as we started talking again a nurse came to measure his sugar level. As this procedure was taking place every 4 hours, Jack followed it on "autopilot." When she wrote the number on Jack's medical record sheet, I asked her, "Is that number good? To my surprise, the nurse looked at me and said, "I do not know, my job is to take the measurement and write it down." She turned to Jack and said, "Young man, see you in 4 hours time."

Two hours later, another "data collecting nurse", as I named them, interrupted us. This time the check was related to the amount of food he had, through the "food making system" located next to his bed. While I tried to understand how this system makes food, what is the frequency of feeding, who chose the "menu", who checks that Jack had enough food to eat and a few other things, he fell a sleep. I learned that the machine makes the food, as programmed, every 4 hours, round the clock. The nutritionists determine the content of the food and the machine "knows" when Jack has had enough to eat!

Grand Fellowship Award to Jack Hessburg

> **"Article 10:** The Akademy shall, at its discretion, recognise individuals who made a significant contribution to the achievement of its purpose

through a Fellowship Award Scheme."[41] The Constitution of the MIRCE Akademy

In the very few days that I had, between learning about Jack's health condition and arranging the trip to Seattle, I quickly administrated the process of the Award of the Grand Fellowship of the MIRCE Akademy to Jack. Within 48 hours the awarding Plaque was made on which the following words were engraved: "For the unique understanding of the maintenance process that was the building block of MIRCE Mechanics", as a reason for the Award.

The Grand Fellowship is the highest Honour that the MIRCE Akademy can bestow upon an individual, in accordance with the Constitution. Since its opening in 1999, the following individuals have been conferred with the title of a Grand Fellow[42]:

- Bader, F.W. Richard (1931-2012), elected in 2010
- Dubi Arie (1945-2015), elected in 2001
- Hessburg, Gregory John (Jack) (1934-2013), elected in 2013
- Mansell Nigel Ernest James, elected in 2000
- Pecht Michael, elected in 2005
- Senna Ayrton (1960-1994), elected posthumously in 2014
- Todt Jean, elected in 2012
- Vacher Polly Mary Anne, elected in 2001

Just before leaving Exeter I informed several of Jack's colleagues from the Boeing Company and several local newspapers about the Grand Fellowship Award to Jack.
I also arranged with the manager of the Centre for a small Fellowship Award ceremony to be held in the "Common Room" on Wednesday 24th July, at 16.00. Also, with the Apollo 13 attitude "failure is not an option" I convinced the head nurse, an ex US Air Force person, to take Jack out in the Garden for an hour. I wished Jack to see the blue sky, which has been his natural habitat during his life. The opportunity to go out to the Flower Garden delighted Jack and he participated very actively in the preparation for this "adventure". Several members of staff helped for Jack to be shaved, dressed and hoisted into a wheel chair ready to go to the fresh air after such long time.

To Jack's huge surprise he was wheeled to the Common Room where several doctors and members of the staff, invited by me, were there to welcome him. With a typical Jack's cheeky smile he looked at me and said, "What is going on here?" I smiled back to him and said, "Ladies and Gentlemen, thank you for coming to the MIRCE Akademy's Grand Fellowship Award to Jack Hessburg." After a few sentences only, I realised that Jack was not comfortable in the rather small wheel chair. Hence, I concluded the ceremony, rather quickly, by presenting the Plaque to Jack. All guests clapped and congratulated Jack for the Award; as for all of them he was just another patient. However, for me, Jack was the first, best and the only Chief Mechanic who ever lived on "Planet Earth". The whole party lasted for about 20 minutes, during which I took a few photographs for the MIRCE Akademy archive on one hand and also for Jack's family, as none of them could be there. Regrettably, but understandably, nobody from those whom I invited from the Boeing Company managed to attend this event. Of course Jack did not know that they had been invited.

After the Fellowship Awards event, the head nurse, Jack and I went to the Flower Garden of the Hospital, where Jack was originally expected to be. That was Jack's first outing, for a long time. I wanted to take him to the fresh air, but even more, I wanted Jack to see the blue sky of Seattle, the place where he spent the most of his time, either by being there or thinking about it. Jack was very happy and talkative. At one moment I said to him, "Jack you retired from the Boeing Company in 1999. During your working life you have done a lot, achieved a lot and you have got lots of professional recognitions, Awards and Honorary Doctoral Degrees, but what really means the most to you?" Without any hesitation Jack looked at me and said, "The fact that United Airline believes that I am their best employee, on the pay roll of Boeing."

[41] http://www.mirceakademy.com/index.php?page=Constitution
[42] http://www.mirceakademy.com/index.php?page=grand-fellows

While lying down under the blue sky, among other topics that we talked about, I asked Jack "What made you think to install the interrogating plugs for the Central Maintenance Computer around the fuselage of the B777?" Without any hesitation Jack replied, "It is a bloody big airplane!"

"I am ready for you to go home"

During this short visit to Jack, I would arrive at 08:00 and stay with him till 20:00. Not knowing the situation, I stayed without any food during the first day. I realised it only when I arrived back at the Hotel! The excitement of seeing Jack alive and the sadness of seeing him in this physical condition, especially during the first hour when no words were coming from Jack, totally suppressed any necessity for food.

The following days on my way to Jack, I would get a sandwich and some fruit for lunch. Surprise, surprise, the smell of fuel attracted me to the nearby petrol station where on day three I got a good cup of coffee and an ice cream, while Jack was napping.

The Fellowship Award party and the visit to the Flower Garden finished around 18.00 Jack was in his own room and his own bed by 18.30. Jack instructed me to put the Fellowship Plaque on the bedside table facing up, next to the model of the B777. For a good, 20 minutes, both of us were quiet, that silence was "telling the whole story" in the way it developed over the last few days and the uncertainty of the future. Then Jack took the remote control device, raised the back support of his bed and said, "I am ready for you to go home." I looked at him and said, "Jack no hurry, I have plenty of time, as my flight is not till tomorrow noon and I have a hotel room booked at the airport for tonight." With Jack's typical "innocent boy face", he looked at me and said, "I owe you a big one for coming to see me. However, it is now time for you to go back." From his facial expression, I clearly "got the message". I came close to Jack, hugged him and quietly left the room.

Of course, I did not want to leave him immediately. I went down to the ground floor and sat down in the Flower Garden, looked at the blue sky, but this time without Jack next to me. Everything looked and felt different, empty and insignificant. After a good half an hour of gazing into the blue sky and thinking about the pleasure, knowledge, friendship and fun, that Jack and I have been sharing, over many years, I was ready to go back to see him again. I slowly walked up to the second floor, and stopped a few metres before room 216. There was nobody in the long corridor, the nurse's bay was also empty, and the only sign of life were sounds from different TV stations coming through the open doors from other rooms, where the majority of patients were not even aware of where they were. I walked pass by Jack's room and saw that he was asleep. I came back and stood at the door to say goodbye to my friend, colleague, teacher, supporter and the person who had significantly impacted my life during the last 20 years. Totally unaware of my presence Jack was sleeping after a rather exciting and interesting day!

I arrived home to England on Friday 26th July full of emotions and worries about Jack's future. As an eternal optimist, I believed the probability of seeing Jack again and telling him about the creation of MIRCE Science was greater than zero. Naturally, I continued exchanging emails with George Yesian, who was extremely helpful. Also, I was thinking of what I could do to make life a little better for my "dear friend" who was now grounded by the physical conditions he really did not want to be in!

The Final Email from Seattle

In the afternoon of the 12th August, I received an email from Justin regarding the final departure of Jack Hessburg, with the following content:

"I received word from Bob Manelski this morning that our mutual friend Jack Hessburg passed away at 0500 this morning. I am unsure how many of you have been receiving Bob's email updates, so it is with regrets I am passing this sad news on.
Jack lived an incredibly full life - an adventurer who visited all 7 continents in his lifetime. On Jack's wall at home is a world map filled with pushpins. As you would expect, every major city was long ago pinned. What always impressed me most about that map is that Jack visited so many places the world has never heard of. Jack used to joke about Ouagadougou, Frobisher Bay and Bobo-Dioulasso, but Jack had actually been to each of those places and hundreds more like them. Jack retired in 1999, but even in his

retirement, Jack seldom sat still for very long. Whenever we spoke, it always seemed he was just arriving home or just getting ready to depart on some new quest, even if it was just a car trip to the high desert in NV, which was one of his favorite spots on earth.
Listening to Jack recount his stories was something I will always remember – especially stories from early in his career. Jack was a flight engineer for Saturn Airways hauling cargo into some of the craziest spots on earth. Jack often laughed about arriving in 3rd world countries, often operating out of dirt strips, and carrying enormous amounts of cash in a money-belt to pay for fuel, repairs, bribes, or other contingencies – all necessities in a time and place where no transaction could be done on credit. He liked to say he had more money in his belt than the entire town he was visiting, and it was almost certainly true. Jack perpetually wore a gold bracelet and a diamond ring – reminders of a former life when he always wanted a universal currency on-hand to help him out of a tight spot.
When my kids were younger, I used to bring them to Jack's house where the stories would just flow. In Jack's living room is a display cabinet filled with relics and mementos from his many adventures – confirmation of his stories and confirmation of Jack as the genuine article. Jack would often pull some item out of the case or from a back closet while telling stories to my kids. They were in awe of Jack. Not only were his stories amazing and entertaining, but when he had told enough stories, Jack liked to sit down and watch Loony Tunes with my kids (Jack had every Loony Tune ever made on DVD. Jack may have been crusty and a bit mean to the average adult, but he truly loved kids.
Jack hired me into the Chief Mechanic's office when I was 24, and for the past 20 years he never stopped calling me "hey kid" – that's the honest truth! I went from being a bit scared of him to realizing he was a very complex man who cared about me very much… even if he had trouble expressing affection! I'm grateful for his friendship. He was a one-of-a-kind man and a dear friend who will be greatly missed."

16th August 2013: MIRCE Akademy Web Site: "Sad News from Seattle"

"Jack Hessburg, the Grand Fellow of the MIRCE Akademy, inspirational professional and great friend of many of us, passed away on Monday 12th August. From the moment when he cut the ribbon and officially opened the Akademy in May 1999 until July 24th 2013 when Dr Knezevic visited him for the last time, Jack was one of us. We shall certainly take all the necessary steps to ensure that he will stay part of us in the future and that his unique experience and a mental ability to see "aircraft maintenance as a process of managing failures, rather than fixing broken parts" will be shared with the future generations of our Students, Members, Fellows and Staff."

From: jk@mirceakademy.com
Sent: Friday, August 16, 2013 12:56 AM
Subject: RE: Jack Hessburg - 1934-2013
"Dear All at Hessburg Family
I wish to share a few photos and the email that I received from the Administrator of Jack's Hospital, regarding the time that I spent with him, at the end of July. Although after terrible dreams he would wake up confused, the rest of the time we had proper, fully conscious conversations about our collaborations, friends and families, as our friendship goes far back as 1997.
Certainly, Jack will never disappear from our thoughts and hearts. We, at the MIRCE Akademy, are making plans to open Jack Hessburg School for Chief Mechanics. I wanted that since early 2000, but Jack was almost embarrassed with my suggestion, telling me that he is not that important. However, when I mentioned that again in the hospital, he agreed with the idea and we decided that the further discussion about it would be during my next visit to him, which sadly will never be materialised. Hence, if any of you might be interested to be involved in this project, please let me know, or you know other people who would like to make Jack's name, knowledge and experience part of the education of the future generations.
Jack you will be missed."

From: Mancini, Lou
Sent: 16 August 2013 14:58
To: jk@mirceakademy.com
Subject: RE: Jack Hessburg - 1934-2013
"Wonderful – thank you!
Lou Mancini
Senior Vice President

Commercial Aviation Services
Boeing Commercial Airplanes
The Boeing Company
Seattle WA "

From: George Yesian
Sent: 16 August 2013 06:33
To: jk@mirceakademy.com
Subject: Re: Message from Dr Knezevic
"I'm so sorry for your loss. Jack had many friends come to visit before he passed. I was taken back by your visit and was encouraged to cherish my own friendships, more brotherly than friends. I'm visiting my best friend tomorrow, in Texas. I'm going to hug him a little tighter and cherish every moment, even more since I met you. You're a good friend to Jack and I know he loves you. Thank you, for your visit. The staffs also were touched by your visit, as we talked about it everyday you were here.
Take care and wishing you the very best. – George."

As I could not travel to Seattle for Jack's Memorial Service that took place at the end of September, I decided to write the farewell words to my friend, colleague, mentor and the most inspirational person I was associated with. I sent the following letter to Jack's nephew, Dr Jeffrey Edelstein, who was a contact point for me.

"To My Chief Mechanic

For me, there are two Chief Mechanics in the entire World, although both of them have the same US social security number. That number belongs to the late John Gregory Hessburg[43], globally known as Jack. He was the world's first Chief Mechanic, the title Jack invented to describe his job, in response to the Boeing Corporation's desire to design maintenance friendly airplanes. In that role Jack become a legend; through the aviation industry "enviable" dispatch reliability that Boeing 777 has demonstrated during the first 18 years in service.

My first knowledge of Jack in this role was through the pages of many professional journals and reports on the new way of developing passenger aircraft. Much of that material was cited in my 1996 System Maintainability book. The book was dedicated to Jack and his visionary boss Allan Mulally, although I have never met them. Then in 1997, during the First Aviation Congress that took place in Los Angeles, I had the privilege of meeting them both. That was the day when "My Chief Mechanic" was created. From that moment to the very last hour of our final encounter, at the end of July 2013 in Seattle, I had many opportunities to learn from Jack and have fun with Jack. This beautiful collaboration "converted" him into my professional idol and personal friend.

*Jack's genius helped me to understand that the word maintenance has two meanings - the common one that is "fixing broken stuff" and his, which is the "management of failures". This realisation fundamentally shaped my philosophy for the **M**anagement of **I**n-service **R**eliability, **C**ost and **E**ffectiveness (MIRCE) that finally led to the creation of the MIRCE Akademy, which was officially opened by Jack in 1999. Even further, his ability to distil the fundamental out of complex and to present it with a unique sense of humour ignited my desire to provide the answer to Jack's life long question*

[43] Jack Hessburg - the first person in aviation history to hold such a post, created in 1990 by Boeing to support its new 777. Hessburg has more than 40 years of experience in aviation, both in maintenance and flight operations. Before joining Boeing in 1973, he had a variety of aviation jobs, including designing fuel cell power plants for Pratt & Whitney Aircraft, Director of Maintenance Training for Civil Air Transport; Director of Flight Crew Training for Saturn Airways; Instructor at Parks College in the Maintenance Engineering and A&P Mechanic Departments, and Systems Engineer at Northwest Airlines. My first job at Boeing was a Flight Operations Engineer supporting a number of United States, African and Middle East operators. In 1980 he joined Field Services, providing on-site support to airlines in San Francisco and subsequently Montreal. In 1986 he returned to a factory assignment as 747/767 Airline Support Manager. Hessburg is both a Mechanical Engineer and an A&P Mechanic. In my current job as Chief Mechanic, he brings the Mechanic's and Air Carrier Maintenance Engineer's perspective to the design table. He is a 1994 winner of the Joe Chase Award from the Flight Safety Foundation and Professional Aviation Maintenance Association. He won the 1995 Commercial Aviation Technical Achievement award from the American Institute of Aeronautics and Astronautics, Pacific Northwest Section. He is an Industrial Fellow of the University of Exeter, UK.

"What is kilogram of maintenance worth?" Today, methods of MIRCE Science are used to quantitatively assess the delicate balance between the cost of designing in "economic redundancy" and its in-service benefit, for all design alternatives.

The corridors of the MIRCE Akademy are echoing Jack's words of wisdom, regarding all aspects of the airplane's life, summarised through numerous anecdotes and phrases of his, which are constantly shared by its students, Members and Fellows.

I strongly believe that it is my professional responsibility, and of course a personal privilege, to expose future generations of engineers and managers to the views of "My Chief Mechanic", who clearly understood the aircraft is not purchased by airlines because it is as a "Nintendo marvel wrapped in aluminium" but because it enables them to conduct transportation business by being at the gate on time to originate the trip to the chosen destination, immortally summarised by Jack:

"All I want to do is to go to Cleveland, on time and never crash."

With respect and love
Dr J. Knezevic, Founder & President of the MIRCE Akademy"

My farewell letter to Jack was displayed during the Memorial Service, some of the attendees have responded through the following emails:

From: Craig Simcox
Sent: 25 September 2013 20:06
To: <jk@mirceakademy.com>
Subject: Re: From Dr K RE: Jack Hessburg - 1934-2013
"I had felt a need on the 767-300 to have more income from the mechanics and service side. When I was asked to join the 777 team, early on we decided to have a Chief Mechanic, similar to the role of Chief Pilot. We would also plant people in each of the Engineering "Design Build" teams along with pilots and manufacturing representatives.
I interviewed and sought help finding a Chief Mechanic. When Jack was brought to my attention I knew we had a match! His experience for the position was outstanding. At first, it was hard for the engineers to accept the idea of mechanics inputs to the DBT's. Jack was super in winning them over. Soon DBT's and airline representatives were calling Jack and the mechanic services team as regular members, depending on their inputs to make the airplane the success it is, of course, renown. Even in service Jack provided sought after information.
I am sorry that I will not be able to attend.
During the 777 Program I was. Director Engineer-Customer Services 777 Craig Simcox, PhD"

From: Zavala, Rafael
Sent: 27 September 2013 13:21
To: <jk@mirceakademy.com>
Subject: RE: To the Members of MIRCE Akademy
"Hello
Sorry to hear about Jack, I had the opportunity to meet him (and even had his autograph!) when I was in Exeter during one of your symposiums, I also admired his work and always thought he was a truly exceptional person.
Thank you for the update and reference to this CALCE paper.
Regards,
Rafael."

From: Mitzi Beno
Sent: 01 October 2013 00:05
To: jk@mirceakademy.com
Subject: Re: Memorial Services Jack Hessburg
"Dear JK
You were very much with us on Saturday during the events of Jack's memorial. The recording of the pictures of Jack's life ran almost constantly during the day from the visitation at the church to the reception afterward, to the dinner at the end of the day. Each of the many, many times I saw the picture of

you standing next to Jack, I remembered your honouring words about him, your supportive emails to us, and you lovingly sharing the memorial internationally with us in spirit. That picture is a treasure you have given us forever, as are you. Both were there on the bridge with us in spirit, as we said our final goodbyes to Jack who had already started on his new set of "out of this world" adventures.
Thank you.
With deep appreciation for your words, you're pictures and your love,
Mitzi Beno"

From: Janice Blum
Sent: 01 October 2013 17:08
To: jk@mirceakademy.com
Subject: Jack Hessburg
"HI JK,
I'm one of Jack's nieces. I wanted to send a personal note of thanks to you for being part of the memorial service and your professional and personal relationship with Jack. He was quite the man. So many, many facets to his life.
Your note, photograph, and most recent awards were all part of the weekend's activities. You were there in spirit as well.
Thank you for sharing your thoughts and experiences with us prior to Memorial weekend. I wish you well in your book development and publishing. May the MIRCE Akademy continue to be successful.
Remember Jack's rules of life:

1. If it's not your problem, it's not your problem to fix!
2. Don't get yourself wound around the axle trying to solve rule #1.

Best Wishes,
Janice Blum"

From: Polly Vacher
Sent: 01 October 2013 16:46
To: jk@mirceakademy.com
Subject: Re: Message for the Fellows of the MIRCE Akademy
"Very nice message - well done! He will be missed but his memory will live on
With love
Polly"

I was thinking how to further honour Jack, whose spirit, wise words and, of course, memorable phrases are constantly present at the MIRCE Akademy. Hence, to respectfully close the professional part of the relationship with Jack, I decided to dedicate the whole MIRCE International Symposium, which has been running for 22 years, to Jack, his work, achievements and legacy.

Index of People Featuring in the Book

The Origin of MIRCE Science

This book is about the journey over the road that the author has travelled since birth till today, but it is not a book about him; it is a book about the quest for the new body of knowledge that he named MIRCE Science, without reasonable excuse! This journey consisted of two paths:

- The first started with his childhood obsession with cars and autosport, progressing to building one by hand, using parts obtained from scrap yards, in a neighbour's garden. Two years later driving that car he earned one point in the National Rally Championship, while experiencing the physical reality of operation, maintenance and support processes.
- The second took the author to universities, libraries, institutes, companies and other organisations worldwide, in the quest for relevant knowledge of science and mathematics, the complexity of which, according to Jack Hessburg (1934-2013), the World's first Chief Mechanic (Boeing 777), required the intellectual effort equal to winning a Nobel Prize!

Both paths converged 40 years later to form MIRCE Science, the theory for predicting functionability performance of functionable system types. MIRCE Science enables designers and project managers to quantitatively predict, life long, positive and negative functionability work and corresponding costs for each feasible option of the future functionable system type, concurrently considering functional solutions with operational, maintenance and support options, by applying MIRCE Science originated: **Functionability, Operability, Maintainability, Supportability** and **Profitability Equations**, the mathematical derivation of which has been fully described in this book.

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