28th MIRCE International Summer School

4 - 6 July 2017 Woodbury Park, Exeter EX5 1JJ, United Kingdom

Mathematical principles of Mirce-mechanics

Dr Jezdimir Knezevic

Researcher, educator and entrepreneur with over 300 publications disseminated world-wide through books, handbooks, papers, monographs and reports are attributed to his name. In addition, he has delivered hundreds of technical presentations, key note addresses and speeches; has been congress, conference, symposium chairman, track leader, workshop presenter, round table moderator on many hundreds international events which took part in all continents.

Dr Knezevic is the father of **Mirce-mechanics**, the science of the motion of maintainable systems through functionability states in time. He is the Founder and President of MIRCE Akademy, an independent research and educational institution based in UK.

His multi-disciplinary theoretical knowledge, considerable "hands-on" practical experience and endless passion for the subject have attracted over 6000 engineers, managers and students to his courses and educational programmes in over 40 countries in Europe, North and South America, Asia, Australia and Africa, at universities, professional institutions, industry and government.

Dr Knezevic has worked in the field of the system functionability theory and its applications to engineering and management for over 30 years.

Full details www.mirceakademy.com

At the MIRCE Akademy we have discovered and faced this problem for many years. During our extensive research studies, by numerous students and members of staff, we have observed and analysed large number of failure phenomena - inherent failures, maintenance errors, foreign object damage, as-bad-as-old repairs, not fault found, ageing processes, storage and transport related phenomena, fatigue cracks, impact of solar radiation, sand, wind, ice on machine durability, material vacancies and many, many more. These failure phenomena required visual checks, inspections, operational tests, non-destructive tests, reliability parameter and indicator monitoring, failure data recording and analysis and those phenomena demanded spares parts, facilities, test equipments, tools and similar resources. We have understood a large number of failure causes, frequencies, and the consequences of their occurrences by studying lives of a large number of maintainable systems. We have quantitatively determined and analytically formulated their relationships. Finally, their **physical relationships** have been captured and described through **mathematical formulas** that enable accurate predictions to be made. All of that has given birth to the *Mirce-mechanics, the science of the motion of maintainable system through functionabilitystates, in respect to time.*

On this occasion we would like to share our knowledge with practising engineers and managers whose business pressure is preventing them from doing this type of research, but who are never the less asked daily to deliver this type of requirements or expectations.

Results of experiments and observations performed thus far unquestionably lead to conclusion that the deterministic regularity found in the continuous motion of functionality, such as speed, acceleration and similar, studied by classical mechanics, cannot be found in respect to the motion of functionability through time. What can be found is discrete motion with statistical variability, as shown in Figure 1.

Thus, functionability trajectories, generated by similar individual systems, under similar circumstances vary among them self, to the degree that no two trajectories are identical. Therefore, the proven formulas of Newtonian mechanics that govern the motion of macroscopic bodies through time cannot be used for predicting the motion of functionability through time, as far as the functionability trajectory is concerned

The relative frequency histogram of the motion of functionability through the life of sample size of 497 systems at specific instances of time is obtained by using well known statistical expression:

$$y'(t) = \frac{\text{Number fo systems in PFS @ t}}{\text{Total Number of Systems Orserved}} \qquad 1.$$

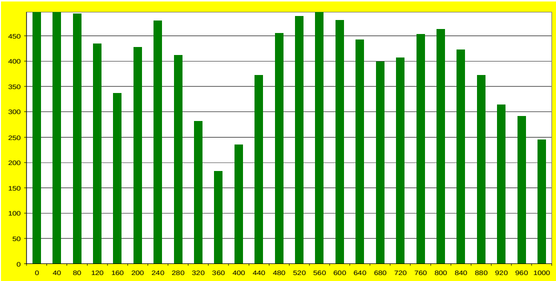

Figure 1: Relative Frequency Histogram of the Motion of Functionability through the life of 497 Systems at specific instances of time

Clearly, functionability histograms can be produced only after the data have been generated, which means after the events. However, the objective of Mirce Mechanics is to develop equation that will be able to predict the data that are going to be observed, in the similar manner as the predictions made by Newton's, Maxwell's, Schrödinger's become confirmed by the future events

Mirce Mechanics Formulas, developed at the MIRCE Akademy, by D Knezevic, are mathematical expressions of the physically observed processes of the motion of systems through functionability states and they define and predict physically measurable properties of system functionability in the probabilistic terms.

The laws of probability are just as rigorous as other mathematical laws. However, they do have certain unusual features and clearly delineated domain of application. For example, it can be readily verify that in the case of a large number of systems failure phenomena will occur in a specific number of the cases, and the law is more accurate the more systems are observed. However, this accurate knowledge will be of no help in predicting the occurrence of functionability events in each individual case. This is what distinguishes the laws of probability: the concept of probability is valid only for an individual event and it is possible to work out a number that corresponds to it. However, it can only be measured when identical tests are repeated a great number of times. Only then can the measured value, the probability, be used to assess the occurrence of each individual functionability event, which is one of the possible outcomes of the test.

The unusual features of the laws of probability have a natural explanation. In fact, most probabilistic events are results of quite complex physical processes, which in many cases cannot be studied or understood in all of its intricacy. Such inability takes its toll, as it is only possible to predict with certainty the average result of numerous identical tests. Thus, for each functionability event it is only possible to indicate its likely outcome.

Probabilistic predictions of the functionability trajectory are based on the framework of the sequence of occurrences of Positive and Negative Functionability Events, whose individual and cumulative times are measured as shown in the Figure below.

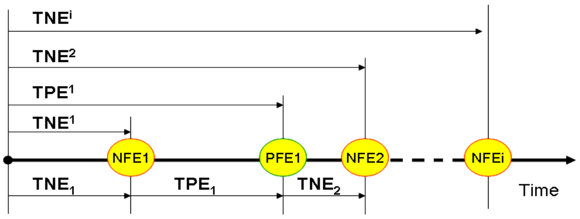

Figure 2: Individual and Cumulative Times to Functionability Events

Based on the Figure 2, the following functions are used:

- Negative Function, $F_i(t)$, which defines the probability that the i^{th} NFE will take place before or at instant of time t is defined in the following way:
  $$F_i(t) = P(TNE_i \le t),\ i = 1, \infty. \qquad 2.$$
- Positive Function, $O_i(t)$, which define the probability that the i^{th} PFE will take place before or at instant of time t is defined by the following expression:
  $$O_i(t) = P(TPE_i \le t),\ i = 1, \infty. \qquad 3.$$
- Probability distribution that defines this event is uniquely determined by the physical properties of the process that generate positive functionability event (replacement, repair, calibration, modification and similar) [9].
- Sequential Negative Function, $F^i(t)$, which defines the probability that the i^{th} sequential NFE will take place before or at instant of time t, is defined as:
  $$F^i(t) = P(TNE^i \le t),\ i = 1, \infty. \qquad 4.$$
- Sequential Positive Function, $O^i(t)$, which defines the probability that the i^{th} sequential PFE will take place before or at instant of time t: is presented in the following manner:
  $$O^i(t) = P(TPE^i \le t),\ i = 1, \infty. \qquad 5.$$

Equations E3 and E4 define the sequence of functionability events for any maintainable system. Having determined the probability distribution and its governing parameters of the times to subsequent functionability event, positive and negative, it is possible to develop a mathematical scheme that will provide opportunity to predict the future sequence of functionability events for any given system. This is the essence of the Mirce Mechanics, which is the only theory available to design engineers to quantitatively predict the consequences of all of their decisions on in-service behaviour of their future systems.

Mirce Functionability Equation

The trajectory of functionability is uniquely defined by the sequence of functionability events, from the birth of the system to its decommissioning. Thus, the fundamental equation of Mirce Mechanics, the functionability equation y(t), that defines the probability of a system being functionable at a given instant of time t is defined as:

$$y(t) = P(PFS @ t) = \sum_{i=0}^{\infty}\left[P(PFS^i @ t)\right] = \sum_{i=0}^{\infty}\left[P\left(TPE^i \le t\right) - P\left(TNE^{i+1} \le t\right)\right]$$

Making use of equations 3 and 4, while bearing in mind that $O_0(0) = 1$, as a system starts its life in positive functionability state, the above expression of functionability equation could be presented in its final form:

$$y(t) = 1 - \varphi(t) + \mu(t) \qquad 6.$$

This expression is developed by the author and it is named Mirce Functionability Equation. It defines the trajectory of a functionability through the probability of a system being in positive functionability state at a given instant of time t.

The unit of functionability determined in accordance to the Mirce Functionability Equation, .is 1 Senna [1S]. It is quantified by the probability of maintainable system being in PFS at a given instant of time.

Making use of existing observational data related to the in-service behaviour of a sample of 497 systems, operating in similar environmental and utilisation conditions, the probability laws that drive shapes of positive and negative functions defined by the equations 2-5 where determined. The obtained functions are shown in Figure 3, where the green lines represent positive functions and the read lines represents negative functions.

The functionability trajectory, calculated in accordance to the expression 6 is shown with a black line in the Figure 3.

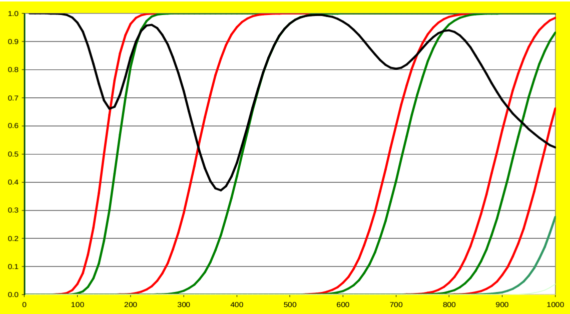

Figure 3: Functionability profile calculated by Mirce Functionability Equation for the Example shown in Figure 1.

Analytical solutions for the Mirce Functionability Equation are seldom possible due to inability of mathematics to deal with the large number of functions and their interactions. These types of problems are not specifically related to the Mirce Mechanics; they are common to all scientific disciplines of this nature, as it is a known mathematical fact that the integral equations do not have analytical solutions. [10]

However, it is necessary to develop computational methods to deal with the mathematical difficulties as it is unacceptable to simplify observed reality of system in-service behaviour in order to cope with mathematical limitations. [11]

For the numerical example used in this paper the result of the application of the Monte Carlo simulation method performed to obtained quantitative solution of the Mirce Functionability Equation is shown in Figure 4 as dots.

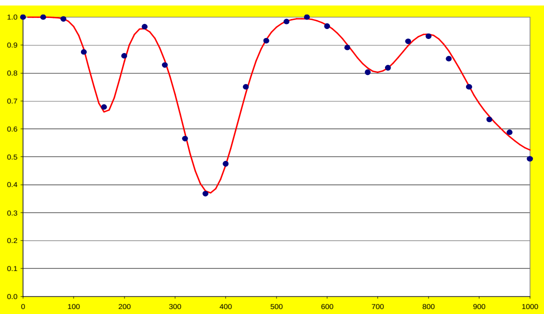

Figure 4: Functionability profile calculated by Mirce Functionability Equation

The Impact of Mirce Functionability Equation on System Engineering and Management

Although science has to be truthful, rather then useful, the body of knowledge of Mirce Mechanics is essential for scientists, mathematicians, engineers, managers, technicians and analysts in industry, government and academia to predict functionability trajectories of the future systems, for a given configurations, in-service rules and conditions, in order to manage functionability events in the way that the functionability performance is delivered through the life of system, at least investment in resources and environmental impact. For that to happened, the science proven method is needed, very much different from the classical scientific knowledge, described trough the type of the equations mentioned in the introductory part of the paper, because functionability performance are defined in the following way:

- Every scheduled flight will leave on time with a probability of at least 0.97 or in other words, it is acceptable to have no more than three delays, on average, out of 100 flights;
- The direct maintenance cost will not exceed 25 % of the purchase cost with a probability of 0.95;
- The probability that the production line will be fully operational during the specified in-service time will be not less than 0.91;
- In system consisting of several systems, at least 90% of them will be operational at all times with a probability not less than 0.925;
- The mission reliability will be greater than 0.98 for missions shorter than 500 hours;
- There should be 5 NFEs among 1000 systems, on average, during the first 10 years of service, with a probability of 0.95.
- Each 10 hour flight will be successfully completed with probability of 0.995, during the first 20 years of operation

Consequently, the only way to address performance targets formulated in the way above is to use concept and principles of Mirce-mechanics to evaluate engineering and management options, at the time when fundamental and irreversible decision are made regarding future systems.

Conclusion

This text clearly demonstrates that functionability performance of any maintainable system is very much different from its functionality performance, in physical, technical, engineering and management sense.

This Summer School also demonstrates that functionability performance is the time dependent property of the system and its motion is manifested through the sequence of transitions through positive and negative functionability states.

Like in the classical mechanics, where the continuous uniform motion is natural state of the macro world that is fully defined and predictable by Newton's equations, or in quantum mechanics where the continuous motion is also natural state of a micro world fully described and predictable by Schrodinger equation, in Mirce-mechanics continuous change in the functionability states is a natural state of maintainable systems during they in-service life, which is fully defined and predictable by Mirce Functionability Equation.

Finally, Mirce Functionability Equation is the scientific foundation of the System Engineering and Management predictions and analysis regarding the motion of functionability through the life of maintainable system.

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Venue

Woodbury Park

Woodbury Park is a magnificent 500 acre complex set among rolling hills above the South West English coastline, only a few miles from Exeter.

Communication between Exeter and other parts of the United Kingdom are excellent. **By road**, the M5 motorway links Exeter to London, the Midlands, Scotland and Wales. Regular rapid coaches run services to and from London and Heathrow Airport. **By rail**, a regular fast service is available to and from Exeter (St David's Station) and London (Paddington Station). **By air**, Exeter Airport offers regular flights to many British and Continental destinations and is situated near to Woodbury Park.

Travel between Exeter and Woodbury normally requires a car or taxi.

Among the outstanding leisure facilities at Woodbury Park are two golf courses including the magnificent **Oaks Championship course**, tennis courts, a swimming pool, spa, sauna and fully equipped gymnasium and well appointed lounge areas and bars.

Woodbury Park, Exeter, EX5 1JJ, UK
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💻 **www.woodburypark.co.uk**

Exeter is the most southwesterly Roman fortified settlement in Britain. Exeter Cathedral was founded in the early 12th century and has several notable features, including an early set of misericord, an astronomical clock and the longest uninterrupted vaulted ceiling in England. **Today,** Exeter is identified as one of the top ten most profitable locations for a business to be based.

Woodbury Park Hotel & Golf Club, Exeter, EX5 1JJ, UK – home of the MIRCE Akademy

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Key Information

Price (GB Pounds £)

Package Type	Fee	VAT	Total
Participant	995	199	**1194**
MIRCE Fellows	975	195	**1170**
MIRCE Members	955	191	**1146**
MIRCE Student	755	151	**906**
MIRCE Retired	555	111	**666**

The Price includes:

- Tuition
- Study Materials
- Lunches
- Light Refreshments
- Summer School Dinner - Fish & Chips Dinner in XVII century English pub on 5th July, Lighter Inn, Topsham

Group Discounts for Standard Participants

2 bookings, from the same organisation will receive a 15 % and for 3 or more 25% discount.

Location and Accommodation

The Summer School will be held at **Woodbury Park Hotel, Golf and Country Club**, which is approximately eight miles from Exeter by road.

Participants are responsible for the arrangement and payment of their own travel and accommodation. **Participants wishing to take advantage of preferential room rates should contact Woodbury Park Hotel Reservations quoting 'MIRCE'.**

The contact details are:

Woodbury Park Hotel, Golf and Country Club, Woodbury, Exeter, EX5 1JJ, United Kingdom

Tel +44 (0) 1395 233 382
Fax +44 (0) 1395 233 384
Email enquiries@woodburypark.co.uk
Web www.woodburypark.co.uk

A list of alternative accommodation in other hotels and guesthouses in the vicinity is available from MIRCE Akademy on request.

Difficulties with the Fee.

Should any interested individual have a problem for paying fees published please contact directly Dr Knezevic, on jk@mirceakademy.com

Travel

For travel details to Woodbury Park and a map visit our website at www.mirceakademy.com.

Messages

During the Summer School participants may be contacted by telephone on +44 (0) 1395 233 85. Messages will be passed to participants during breaks.

Language

The Summer School language will be English.

Recommended Attire

Smart casual is recommended dress code for the Summer School and in the in the grounds of Woodbury Park.

No formal dress is required for the Summer School Dinner.

Smoking

Woodbury Park does not permit smoking in any of the leisure and sport complex facilities and in the hotel.

Mobile Phones

Out of consideration to speakers and the audience, mobile phones should be switched off during the formal sessions.

Further Information

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💻 **www.mirceakademy.com**

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Booking Form

Please photocopy for each additional participant

Terms and Conditions

Substitution of participants may be made at any time. If you intend to do this, please advise MIRCE Akademy as soon as possible.

Cancellation of a booking must be received in writing by the organiser at least 14 days before the commencement of the event in order to receive a refund of payment. MIRCE Akademy regrets that no refunds will be made after the deadline.

MIRCE Akademy reserves the right to change the advertised programme or location or to cancel the event at its discretion. In the event of cancellation of the event by MIRCE Akademy payments received at the cancellation date will be refunded. All places offered are subject to availability.

MIRCE Akademy is not responsible for any loss or damage as a result of substitution, alteration or cancellation of the event.
Mirce Akademy is unable to accept liability for the loss of, or damage to, the belongings of those attending the event.

Participant Details

Surname	
First Name	
Position	
Department	
Organisation	
Address	
Zip/Post Code	Country
Telephone	Fax
Email	
Special Dietary Requirements	
I understand and accept the terms and conditions and payment as shown.	
Signature	Date

Payment Method

☐ Cheque	
I enclose a cheque for GB £	payable to Mirce Science Ltd.

☐ Bank Direct Transfer
Please contact us for details.

☐ **Credit Card**	
Please debit my credit card ☐ Visa ☐ MasterCard ☐ Amex	
Cardholder	
Card No.	
Expiry Date	Security Code
Cardholder's Signature	

☐ **Invoice**	
Please invoice my organisation:	
Department:	
For the attention of:	
Purchase Order No.	
Address (if different from above)	
City:	Zip/Post Code
Country	

Value Added Tax (VAT)

Unless special exemption arrangements exist, under UK Customs and Excise regulations participants from all countries are required to pay UK VAT @ 20 % at the time of publication. Non-UK participants may be able to recover VAT incurred via the relevant tax authority in their country of origin.