Publication of the MIRCE Akademy

2017 Annals of MIRCE Science

"The goal of a scientist is to uncover new ideas, concepts and tools, practical or theoretical, that extend our understanding of the world around us and enable us to do new things. One must believe in what one is doing and stay the course. Now of course, in science one can ultimately prove the correctness of one's work by appeal to experiment and established theory. But even with this buttressing of one's ideas, acceptance can be a long and difficult road."

Richard F.W. Bader (1931 – 2012)
Grand Fellow of the MIRCE Akademy

Publication Date: 31 December 2017

Publisher:
MIRCE Science Limited
Woodbury Park
Exeter
EX5 1JJ
United Kingdom

Phone: +44 (0) 1395 233 856
Email: quest@mirceakademy.com
Website; www.mirce.com

Price:	**General Public:**	**£95.00**
	MIRCE Akademy Fellows:	**£75.00**
	MIRCE Akademy Members:	**Free of charge**

For any questions regarding the Annals of Mirce-mechanics, please send an email to: quest@mirceakademy.com

Order Form: http://www.mirceakademy.com/uploads/Order%20Form-%20MA%287%29.pdf

To become a Member of the MIRCE Akademy please follow the link:
http://www.mirceakademy.com/index.php?page=Membership

Content

MIRCE Science

The philosophy of MIRCE Science is based on the premise that the purpose of existence of functional systems is to do a work, which is perceived as delivering of function through time, like transportation, communication, computation, protection, and others, with measurable functionality performance, like speed, capacity, frequency, power and similar physical properties. As all physical phenomena associated with functionality performance are characterised by certainty, reversibility and independence of time, location and human influences, it can be accurately predicted, at the design stage, by applying known laws of natural sciences, such as: Newton's laws of motion, Maxwell's law of electrodynamics, Coulomb's law of solid friction, Boltzmann's law of thermodynamics, Hook's law of stress and strength, to name a few.

While doing the work, functional systems are exposed to complex interactions between their consisting parts on one hand and the impacts of natural environment and human actions, on the other. As result a variety of mechanical, electrical, chemical, thermal, radiant and other types of energy are generated, some of which affecting the ability of systems to function, known as functionability[1]. Hence, actions like servicing, repairing, testing, replacing, changing the mode of operation and similar must be performed on functional systems to enable them to continue doing the work. Experience teaches us that the information regarding functionability performance of functional systems, namely the amount of work[2] done by and on the system and the resources used for both, is almost non-existent at the beginning of their in-service life. The reason being, all associated functionability phenomena are characterised by uncertainty, discontinuity, irreversibility, inseparability, and are dependent on time, location and human influences. Hence, the known laws of natural sciences cannot be used to predict functionability performance of functional systems.

To seek the body of knowledge that enables the accurate predictions of functionability performance of future functional systems to be made, at the design stage when it is possible to achieve the best compromise between competing solutions, rather than to wait for the users to measure functionability performance, Dr Jezdimir Knezevic resigned from the Research Centre for Managing Industrial Reliability, Cost and Effectiveness, MIRCE, at Exeter University in UK, in 1999, to established the MIRCE Akademy at Woodbury Park, Exeter, UK. Staff, Fellows, Members and students of the Akademy have endeavoured to subject in-service behaviour of functionable systems[3] to the proven methods of science and mathematics to:

1. Physically observe and measure their functionability performance that are quantified through the work done by a functionable system (positive) and

[1] Functionability, n. ability to deliver expected function, Knezevic, J., Reliability, Maintainability and Supportability – A probabilistic Approach, Text and Software package, pp. 291, McGraw Hill, London 1993. ISBN 0-07-707691-5

[2] 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 man-hours of maintenance 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.

[3] Functionable system constitutes of a functional system and the set of the rules that govern associated functionability processes, responsible for delivering functionability performance

the work done on functionable system throughout in-service life (negative), together with the resources consumed in these processes, to determine the patterns of their behaviour in respect to time.

2. Scientifically understand physical phenomena and human actions that govern occurrences of functionability events[4] through life of functionable system types to the level of the dimensional fidelity ranging 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, which are characterised by uncertainty, discontinuity, irreversibility, inseparability, and dependence on time, location and humans.

Decades of research have generated a theoretical body of knowledge, named MIRCE Science, which 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, given rules (related to the operational scenario, environmental conditions, maintenance policies, support strategy) and in-service constraints.

[4] Any event, induced by nature or humans, which impacts the functionability performance of functionable systems.

Physical Reality of Mirce-mechanics- Part 1: Atomic World

Dr J. Knezevic,
MIRCE Akademy, Woodbury Park, Exeter, EX5 1JJ, UK

Abstract

This paper, through three parts, provides an introduction to the Mirce-mechanics, a new discipline that studies the in-service behaviour of in-service life of maintainable systems in order to develop a scientific methods for the prediction of their functionability performance. The in-service life is viewed as a sequence of occurrences of functionability events that are taking place in the direction of time. The main argument provided here is that successful prediction can be achieved only by understanding the mechanisms that drive physical processes, which generate the occurrence of functionability events. It is author's strong conviction that the understanding of those processes must be placed within the physical scale that will provide adequate level of fidelity. That scale is ranging from the size of Atomic System (10^{-10} metre) and by the Solar System (10^{10} metre) on the other. Analysis and research performed in any "smaller scale" would not give the fidelity of observations which could lead to prediction errors. Part 1, is focussed on the fundamental aspects of atomic world and its impact on the functionability events in the world of maintainable systems, as perceived by the author.

1. Introduction

Humans have ability to know things, i.e., the faculty of creating links between them and establishing a chain of cause and effect. Different times in history saw different ways of realising these human capabilities. Our age is an age of science. We have become so used to identifying the concepts "knowledge" with "science" that we cannot conceive any other knowledge than scientific knowledge.

The essence of the scientific method can be explained quite simply. The method enables knowledge about phenomena to be obtained that can be checked, stored and passed on to other generations. It follows that science does not study phenomena in general, but only recurrent phenomena. It is mainly interested in seeking laws governing these phenomena.

Science has been created by humans for humans, and its ultimate purpose of all concepts is to explain and predict things that affect our senses or machines.

Science, as we know it today, started with Galileo, who is regarded as the father of experimental physics, and Newton who is the originator of theoretical physics. In their time, of course, physics was considered a united and indivisible science. In fact, there was not even physics as such for it was then called natural philosophy. However, this division is very significant. It enables us to bring out the two aspects of scientific method, namely, experiment and mathematics.

Science started when people learned to single out simple regularities from the chaos of available facts. It relies routinely on the analysis of facts and search for cause-effect relations, to find an eternal law, confirmed by another scientist by experiment.

The scientific method has transformed the world we live in. It has populated this world with machines, it has given sufficient food to people and protected them from diseases. Triumphs of the scientific method have engendered and strengthened a new faith – a faith in science. The change caused by scientific method in the minds of people is only comparable with such great religious concepts as Buddhism, Christianity, Islam and others. This all become possible due to a discovery that many things in nature can be described using numbers with equations establishing the relationships between them.

The power of science lies in its universality. Its laws are free from the arbitrariness of people; it only represents their collective experience, independent of age, nationality, rank, or frame of mind. It has a criterion of truth and its language does not contain the words “like” and “dislike”. In science truths are proved and phenomena are explained.

2 Mirce-mechanics

Mirce-mechanics is a new discipline that is defined by the author as the study of the in-service behaviour of maintainable systems. To make the clear different between the systems, whose life ends up, as far as designers are concerned, by delivering them to the customers, whose performance is measured through functionality performance, In Mirce-mechanics,: a set of components put together to deliver measurable functionality performance together with rules and actions required to maintain measurable functionability performance. It considers in-service life is a sequence of functionability events along the time axis. Its objectives are to:

- Understand physical processes and factors that determine the system in-service life,
- Generate rules and methods that analytically describe their functional relationships
- Systematically predict the in-service life of the system in time and space.

The word System is used as a generic term to represents all maintainable and managed products, constructions and organisations created to deliver function(s) with a measurable performance and attributes. The aggregate term for function, performance and attributes is functionability.

To deliver functionability in time domain all maintainable systems must engage in in-service processes that consist of the flow of operation, maintenance and support tasks. Successful execution of these in-service tasks, in time and space, ii connected with a necessary type and quantity of resources like personnel, equipment, facilities, tools, data and material.

In-service experience teaches us that irrespective of how good the maintainable system may be, interruptions in the provision of the functionability will occur during its life, caused by:

- inherent deficiencies of materials, design and production processes
- irreversible processes that take place in the system itself,
- interaction of the system with its in-service environment,
- planned execution of in-service and maintenance tasks
- insufficient in-service and maintenance resources.

However, the flow of the system functionability through its in-service time is not a deterministic process and cannot be treated with the same degree of certainty as the system's performance, weight and other physical characteristics. To deal with variability, inherent in the system itself and in its in-service interactions with natural, human and business environments, Mirce-mechanics draws on the concept of probability. The role of probability is to facilitate the prediction, as it is impossible to know exactly what sequence of events a in-service life of maintainable system will consist of.

3. In-service Life of Maintainable Systems

In-service life of maintainable systems is a sequence of functionability events that take place in the time domain. Functionability events are occurrences that alter the in-service future of the system or cause the instant change of the state of the system. However, functionability events are direct consequences of the in-service processes that are taking place during the lifr of a system. Those processes could be internal or external to the maintainable system itself. Table 1 gives the list of observed in-service processes or events that the students, members of staff or Fellows of the Mirce Akademy have collected during an extensive period of research.

Table 1. Some of the observed processes/events that impact system in-service life

Lost concentration	Stressed operator	Software error	Frost damage
Expanded	Scored	Dirty	Parts missing
Air starved	Fused	Bogus part	Corroded
Overheated	Incorrect surface finish	Speeding	Incorrect wiring
Grooved	Maintenance error	Incorrect tension	Rotted
Oil saturated	Stretched	Undersized	Faded
Blocked	Bonding unsatisfactory	Smashed	Bird strike
Computer virus	Incorrect assembly	Twisted	Distorted
Shrunk	Incorrect rating	Faulty part	Torn
"Wrong snow"	Thunderstorm	Absent operator	Broken
Incorrect installation	Oversized	Contaminated	Fatigued
Software error	Vandalism	Head wind	Coalition
Transport damage	Battlefield damage	Drunk operator	Punctured
Spun off	Discoloured.	Run out of fuel	Melted
Seized	Typing error	Eroded	Perished
Poor electrical joint	Inspection	Incorrect focused	Damp

High/Low resistance	Shark bite	Weld defective.	Discouraged
Renewal	Replacement	Lubrication	Modification
Short circuit.	Incorrect adjustment	Scratched	Burnt
Power cut	"Too fine sand"	Bent	Charging
Communication error	Dented	Incorrect storage	Noisy
Head wind direction	Rodent attack	Blistered	Solar radiation
Calibration	Overhaul	Cleaning	Repair
Unbalanced	Incorrect drawing	Transport damage	Lost
Frayed	Adjustment	Testing	Bad weather

4. The Physical World

Fully aware that the future in-service life of maintainable system cannot be improved by doing better statistics on the recorded data related to the past in-service life, the Mirce™ Science Laboratory set to collect the physical evidence about the mechanisms that drive system in-service process and originate functionability events. Having collected the "physical evidence" about the events in the system in-service process the MIRCE Akademy set up a very detailed research programme with the objective of understanding them.

In order to understand system in-service processes it is necessary to understand the mechanisms that generate the motion. That represented a real challenge. Answers to the questions "what is the real cause of say, fatigue, the wind direction change, suncups formation on the blue ice runway, faulty weld, bird strike, perished rubber, maintenance induced error, carburettor icing", to name just a few, have to be provided. Without accurate answers to those question the prediction of their future occurrences is not possible, and without ability to predict the future, the use of the word science become inappropriate.

After a numerous discussions, studies and trials, it has been concluded that any serious studies in this direction, from Mirce-mechanics point of view, have to be based between the following two boundaries:

- the "bottom end" of the physical world, nothing bigger than the atom system,
- the "top end" of the physical world, nothing smaller than the solar system.

This range is the minimum sufficient "physical scale" which enables the understanding of cause-effect relationships between system in-service processes and system functionability events, and provides enough information for the accurate predictions to be made. In other words, this is the physical range within which, the system in-service processes mentioned above (fatigue, the wind direction change, suncups formation on the blue ice runway, bird strike, perished rubber, carburettor icing) take place and could be understood.

4.1 The Bottom End: Atomic System

The basic building block of matter is an atom. It is the smallest unit into which matter can be divided without the release of electrically charged particles. It also is the smallest unit of matter that has the characteristic properties of a chemical item. As such, the atom is the basic building block of chemistry. Currently, there are 109 elements out which 89 are natural. [6]

Most of the atom is empty space. The rest consists of a positively charged nucleus of protons and neutrons surrounded by a cloud of negatively charged electrons. The nucleus is small and dense compared to the electrons, which are the lightest charged particles in nature. Electrons are attracted to any positive charge by their electric force; in an atom, electric forces bind the electrons to the nucleus.

All atoms are roughly the same size, whether they have three or 90 electrons. Approximately 50,000,000 atoms of solid matter lined up in a row would measure one centimetre. A convenient unit of length for measuring atomic sizes is the angstrom Å, defined as 10^{-10} metre. The radius of an atom measures between 1 and 2 Å.

Compared with the overall size of the atom, the nucleus is even smaller. In volume, the nucleus takes up only 10^{-14} of the space in the atom. A convenient unit of length for measuring nuclear sizes is the femtometre (fm), which equals 10^{-15} metre. The diameter of a nucleus depends on the number of particles it contains and ranges from about 4 fm for a light nucleus such as carbon to 15 fm for a heavy nucleus such as lead. In spite of the small size of the nucleus, virtually all the mass of the atom is concentrated there. The protons are massive, positively charged particles, whereas the neutrons have no charge and are slightly more massive than the protons. The fact that nuclei can have anywhere from one to about 250 nucleons accounts for their wide variation in mass. The lightest nucleus, that of hydrogen, is 1,836 times more massive than an electron, while heavy nuclei are nearly 500,000 times more massive.

Although electrons exhibit complicated behaviour within an atom, they are characterised completely by a few parameters. The intrinsic properties of an electron are its charge, mass, an internal motion called spin, and magnetic moment. It may be better to call them “quanta”, to register the difference between the classical, distinguishable particle and a quantum being like an electron. All electrons have identical properties. This exact equality is not merely statistical. To high precision, there is no variation in whatever aspect from electron to electron. In contrast, in classical physics, one would expect a certain spread in these values, if one imagined electrons to be small physical objects. After all, in biology, the different individuals in a certain species differ slightly, through not so much as to pass certain bounds that define the species. Electrons are all radically equal. An electron’s individuality is its species, and nothing more, it is always an instance of electronhood, never a “noninstantiable” individual. Because of this, the term “particle” is misleading, since it suggests a body with certain characteristic features or markings, or at least capable of being marked in some way. As Schodinger emphasised, only are all electrons exactly alike in their observable characteristics, there is no way one electron could be marked so that it could be distinguished from the others. One must let go of the preconception that one could pick out a certain electron either by noticing some characteristic features or by marking it, so that one could follow its subsequent life path. As no human language had an adequate word for their condition ("lack of individuality" misleadingly implies that electron should have individualities, but are defective) Pesic in introduced a new word: *identicality*. It means that the members of species have identity only as instances of that species, without any features that distinguish one individual from another. It signifies the exact negation of individuality; it includes total indistinguishability and complete equality of all observable features. It has no inherent reference to time or space, and so experimentally all electrons have the same features whenever or wherever they are observed. [11]

As the lightest charged particles in existence, electrons are absolutely stable because they cannot decay into smaller units. The spin of the electron provides it with a directional orientation. The electron has a magnetic moment along its spin axis. Electrons are subject not only to the electromagnetic force but also to the force of gravity and the so-called weak interaction, the force primarily manifested in the radioactive decay of nuclei. Most properties of atoms—particularly those associated with chemical bonds, physical forces, and the properties of bulk matter—depend solely on the behaviour of the electrons surrounding the nucleus. The chemical properties of an atom depend on the arrangement of its electrons making up the cloud around the nucleus. The atoms of one element differ from those of other elements in the number of their electrons. [9]

If chemical items are building blocks, then compounds are the buildings. Compounds are made of two or more different atoms that are chemically joined. The atoms in compounds are always in definite proportions by weight. The compounds cannot be separated by purely physical means.

Matter is a material substance that constitutes the observable universe and, together with energy, forms the basis of all objective physical phenomena. Matter in bulk may have several states, the most familiar of which are the gaseous, liquid, and solid states. Less clearly definable but also referred to as states of matter are plasma, clusters, and amorphous conditions such as the glassy state. Each such state exhibits properties that distinguish it from the others. Moreover, these general states can be subdivided into groups according to particular types of properties. Solids, for example, may be divided into metallic, ionic, covalent, or molecular based on the kinds of bonds that hold together the constituent atoms.

Matter has two fundamental properties: mass and volume. The mass of a body is a measure of its inertia, though it is commonly taken as a measure of the amount of material contained in the body. The volume is the amount of space it occupies.

4.2 The Top End: Solar System

To be covered in Part 2.

4.3 The Media between; Human World

To be covered in Part 3.

5. Examples

The following two examples are used to illustrate the necessity for considering in-service life of maintainable system and system functionability events through the physical scale adopted by of the Mirce-mechanics.

5.1 Atomic World

5.1.1 Material Imperfection

The purpose of this analysis is to briefly describe some types of imperfections, understanding of which is essential for gaining insight in behaviour of materials which are in turn one of the main drivers of system functionability events.

System failure, as one of the possible functionability events, could originate as a result of imperfections in material that may:

- reduce the overall strength of the material,
- provide preferential paths for the propagation of cracks,
- act as notches,
- serve as sites for preferential pitting-type attack,
- provide paths for intergranual corrosion.

Failures related to segregation, lamination, inclusions, porosity, voids and similar causes are often encountered in real life situations.

Pure crystalline materials are characterised by the remarkably perfect order with which the atoms are arranged. In a typical specimen of a pure metal, less than one atom in a hundred thousand lies within one atomic diameter of a place where there is a mistake in the occupation or arrangements of the sites. However, it is events that occur only at the rare imperfect regions that determine the structure sensitive properties of a material.

A perfect crystal is one composed of identical atoms or atom groups located at the points of a space lattice so that the surroundings as viewed from any one of the points are identical. Obviously crystals of finite size cannot be ideally perfect in this sense because some of the atoms will be at or near bounding surfaces. Another inevitable type of imperfection is the thermal displacement of atoms from the lattice points. In a real crystal, the lattice points represent only the average positions of the atoms, the temperature being a measure of their vibration energy.

However, crystals are rarely perfect. Many of the important properties of crystalline materials are determined by various imperfections in them. The imperfections that can be described as disruptions in the space lattice are called lattice imperfections and can be characterised geometrically, according to whether the centre of the disruption is at a point, along a line, or over a surface. Real crystals usually are not composed simply of identical atoms on identical sites throughout a regularly repeating three-dimensional lattice. They contain imperfections or defects. The imperfections that disrupt the structure most are the imperfections in the space lattice. Since the space lattice is a geometric concept, it is natural to classify lattice imperfections geometrically. Thus, zero-dimensional (point), one-dimensional (line), and two-dimensional (surface) imperfections are treated separately.

Point imperfection: This is a very localised interruption in the regularity of a lattice. A point imperfection comes about, as a rule, because of the absence of a matrix atom (an atom that would be present in a perfect crystal), the presence of an impurity atom, or a matrix atom in the "wrong" place (a site not occupied in the perfect crystal). The absence of an atom from a normally occupied site is called a vacancy.

Line imperfections: Like point imperfections, are defined by the way in which their presence causes disruptions in what otherwise would be a perfect space lattice. As the name implies, the distortion around a line imperfection is centred along a line; thus the imperfection can be considered as the boundary between two regions of a surface which are perfect themselves but are out of register with each other.

Surface imperfections: This type of failure of a structural nature arises from a change in the stacking of atomic planes across a boundary. The change may be one of the orientation or of the stacking sequence of the planes. Grain boundaries are those surface imperfections that separate crystals of different orientations in a polycrystalline aggregate. As a result the boundary atoms in two randomly orientated grains cannot have a perfect complement of surrounding atoms; as a result, a region of transition exists in which the atomic packing is imperfect. In three-dimensions, this transition occurs across a surface separating the grains.

According to Callister [4] the equilibrium number of vacancies, $N_{v,}$ for a given quantity of material depended on and increases with temperature according to:

$$N_v = N \exp(-Q_v / kT) \, ,$$

where N is the total number of atomic sites, Q_v is the energy required for the formation of vacancy, T is the absolute temperature in Kelvins, and k is the gas or Boltzmann's constant (k=1.38x10^{-23} J/atom-K, or 8.62x10^{-5} eV/atom-K, depending of the units for Q_v).

Thus the number of vacancies increases exponentially with temperature. For most metals, the fraction of vacancies, N_v/N just below the melting temperature is on the order of 10^{-4}, that is, one lattice site out of 10000 will be empty. As ensuing discussions indicate, a number of other material parameters have an exponential dependence on temperature similar to that of the equation above. [4]

For example, the equilibrium number of vacancies per cubic meter for copper at 1000°C, could be determined in the following way. The energy for vacancy formation is 0.9 eV/atom, the atomic weight and density, at this temperature, for copper are 63.5 g/mol and 8.4 g/cm^3, respectively. Thus, the number of atomic sites per cubic meter for copper , from its atomic weight A_{Cu}' its density ρ, and Avogadro's number N_A, is equal to:

$$N = \frac{N_A \times \rho}{A_{Cu}} = \frac{(6.023 \times 10^{23} atoms/mol)(8.4 g/cm^3)(10^6 cm^3/m\ )}{63.5 g/mol} = 8.0 \times 10^{28} atoms/m^3$$

Thus, the number of vacancies at 1000°C (1273°K) is equal

$$N_v = N \exp(-\frac{Q_v}{kT})$$

$$= (8.0 \times 10^{28} atoms/m^3)\exp(-\frac{(0.9eV)}{(8.62 \times 10^{-5} eV/K)(1273K)} = 2.2 \times 10^{25} vacancies/m^3$$

5.1.2 Corrosion Process

It has been estimated that approximately 5% of an industrialised nation's income is spent on corrosion prevention and the maintenance or replacement of products lost or contaminated as a result of corrosion reactions.

Corrosion is the primary means by which metals deteriorate. Most metals corrode on contact with water (and moisture in the air), acids, bases, salts, oils, aggressive metal polishes, and other solid and liquid chemicals. Metals will also corrode when exposed to gaseous materials like acid vapours, formaldehyde gas, ammonia gas, and sulphur containing gases.

Corrosion specifically refers to any process involving the deterioration or degradation of metal components. Corrosion processes are usually electrochemical in nature, having the essential features of a battery. When metal atoms are exposed to an environment containing water molecules they can give up electrons, becoming themselves positively charged ions, provided an electrical circuit can be completed. This effect can be concentrated locally to form a pit or, sometimes, a crack, or it can extend across a wide area to produce general wastage. Localised corrosion that leads to pitting may provide sites for fatigue initiation and, additionally, corrosive agents like seawater may lead to greatly enhanced growth of the fatigue crack. Pitting corrosion also occurs much faster in areas where microstructural changes have occurred due to welding operations.

Corrosion is the disintegration of metal through an unintentional chemical or electrochemical action, starting at its surface. All metals exhibit a tendency to be oxidised, some more easily than others. A tabulation of the relative strength of this tendency is called the galvanic series. Knowledge of a metal's location in the series is an important piece of information to have in making decisions about its potential usefulness for structural and other applications.

As the rusting of steel is the best known case of corrosion let us briefly analyse it. Rusting of iron consists of the formation of hydrated oxide, $Fe(OH)_3$, $FeO(OH)$, or even $Fe_2O_3H_2O$. It is an electrochemical process that requires the presence of water, oxygen and an electrolyte. In the absence of any one of these rusting does not occur to any significant extent. In air, a relative humidity of over 50% provides the necessary amount of water and at 80% or above corrosion of bare steel is worse.

When a droplet of water containing a little dissolved oxygen falls on a steel pipe, the solid iron or Fe(s) under the droplet oxidises: Fe(s) $\rightarrow$ Fe^{2+}(aq) + $2e^{-}$. The electrons are quickly consumed by hydrogen ions from water (H_2O) and dissolved oxygen or O_2(aq) at the edge of the droplet to produce water:$4e^{-}$ + $4H^{+}$(aq) + O_2(aq) $\rightarrow$ $2H_2O$(l). More acidic water increases corrosion. If the pH is very low the hydrogen ions will consume the electrons anyway, making hydrogen gas instead of water: $2H^{+}$(aq) + $2e^{-}$ $\rightarrow$ H_2(g) . Hydrogen ions are being consumed by the process. As the iron corrodes, the pH in the droplet rises. Hydroxide ions (OH^{-}) appear in water as the hydrogen ion concentration falls. They react with the iron(II) ions to produce insoluble iron(II) hydroxides or green rust, thus:

$$Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s).$$

The iron(II) ions also react with hydrogen ions and oxygen to produce iron(III) ions:

$$4Fe^{2+}(aq) + 4H^{+}(aq) + O_2(aq) \rightarrow 4Fe^{3+}(aq) + 2H_2O(l).$$

The iron(III) ions react with hydroxide ions to produce hydrated iron(III) oxides (also known as iron(III) hydroxides):

$$Fe^{3+}(aq) + 3OH^{-}(aq) \rightarrow Fe(OH)_3(s).$$

The loose porous rust or $Fe(OH)_3$ can slowly transform into a crystallised form written as $Fe_2O_3.H_2O$ the familiar red-brown stuff that is called "rust". Since these processes involve hydrogen ions or hydroxide ions, they will be affected by changes in pH. With limited O2, magnetite is formed (Fe_3O_4).

Having just explained the process of corrosion it is normal to ask a question: where does oxygen come from? To answer that question became know only in the XIX century as a result of an international constellation of science, who established that 0.1 percent of sunlight causes in green leaves the transformation of carbon dioxide and water into sugar, starch and wood fibre with the release of oxygen.

Man and the entire animal kingdom on Earth are in all respects dependent on this process: we breathe atmospheric air, eat bread baked from cereals, drink milk produced on pastures. But just as we are generally unconscious of the air we breathe, so we rarely trouble ourselves with the thought of a cosmic role of plants, for they are only living things on Earth capable of catching the energy of solar radiation and turning in into the chemical energy of organic compounds needed to support the life on animals and man.

Chemical aspect of photosynthesis proceeds in the following manner [7]: a water molecule, H_2O combines with a carbon dioxide molecule, CO_2, and forms a building block, CH_2O for many organic compounds (for example, glucose $C_6H_{12}O_6$, or $(CH_2O)_6$ consists of six blocks). That is:

$$CO_2 + H_2O \rightarrow CH_2 + O_2 - 5eV\ .$$

This atomic restructuring requires much energy: 3.33 eV to break the bonds between the hydrogen and oxygen in the water molecule and 1.68 eV more to remove the oxygen atom from CO_2. This atom then combines with another oxygen atom from molecule H_2O to yield the molecule O_2. The green leaf takes the required energy from the flux of sunlight quanta. Each chemical bond is formed by a pair of electrons. Therefore, when two hydrogen-oxygen bonds are broken four electrons have to be shifted. It was found that for this purpose at least eight quanta of red light are needed, i.e. two quanta per electron. Therefore, the detailed photosynthesis equation has the form:

$$CO_2 + H_2O \rightarrow 8h\nu \rightarrow CH_2O + O_2 .$$

A quantum of red light with a wavelength of 7000 angstroms has an energy of 1.8 eV, and the total energy of eight quanta is 14.4 eV. One third of this energy is stored as the energy of chemical bonds in the glucose molecule. Hence, when human drink sweet tea and breathe, the oxygen molecules picked up by haemoglobin combine in the presence of enzymes with glucose molecules in the reverse reaction liberating the energy of sunlight stored by chlorophyll, which in the final analysis supports our life. Thus,

$$CH_2O + O_2 \rightarrow H_2O + CO_2$$

The simplicity of the photosynthesis equation is misleading: this is not just another reaction but, rather, a complex biochemical process, which incorporates several stages and, dozens of various reactions.

6. Mirce-mechanics and Engineering Design

Science does not have to be useful, science only needs to be truthful (testable by observation). A. Dubi

However, there is an endless list of practical applications of science that fundamentally have changed the life of humans and to a certain extend altered the natural world.

The concept of design, of making something that has not existed before, is central to engineering. However, Petroski in [8] argues that “the concept of failure, mechanical and structural failure, is central to understanding engineering, for engineering design has as its first and foremost objective the obviation of failure. Colossal disasters that do occur are ultimately failures of design, but the lessons learned from those disasters can do more to advance engineering knowledge that all the successful machines and structures in the world. Indeed, failures appear to be inevitable in the wake of prolonged success, which encourages lower margins of safety. Failures in turn lead to greater safety margins and, hence, new periods of success. To understand what engineering is and what engineers do is to understand how failures can happen and how they can contribute more than successes to advance technology.

6.1 Atomic World

To illustrate the potential benefit of Mirce-mechanics to the system design process, let us look at the corrosion process again. When designing against corrosion, one of two general philosophies may be adopted:

*If attack proceeds fairly slowly and at a reproducible and predictable rate***,** a 'corrosion allowance' may be built into the design, so that a safe material thickness remains at all points after the anticipated lifetime of the structure. Typical phenomena that may be addressed in this way include dissolution of steel in acid media and elevated temperature oxidation. A limitation of this approach is the accuracy of the predictive tools or 'corrosion models' available and it may be appropriate to perform non-destructive evaluation of the actual rate of corrosion during service or at shutdowns, so that the corrosion model can be refined periodically. Thus the actual useful life of the item may be determined with greater accuracy than via use of a model alone. To assist this approach, the environment may be modified to reduce corrosion rates, where practicable.

*If attack may become localised and propagate rapidly once initiated***,** e.g. pitting and crevice corrosion of corrosion resistant alloys, it is normal to design so that attack can never initiate. This requires appropriate material selection. The simplest approach to materials selection is to rely on previous experience, although it is essential to understand the operating environment, so that changes between past and future service regimes can be accounted for. Where previous successful experience does not exist, materials testing may be required to demonstrate fitness for purpose. Testing typically seeks to recreate the principal components of the service environment, whilst increasing the aggressiveness, to obtain a suitably short test exposure period. This may be achieved by increasing temperature, increasing the concentration of certain environmental species or by forcing electrochemical changes.

A similar approach may be taken when designing against stress corrosion cracking, e.g. chloride stress corrosion cracking of austenitic stainless steel and sulphide stress cracking of carbon steels, where any crack initiation is considered unacceptable due to the rapid rate of subsequent propagation. In this case, three factors contribute to cracking

- material type and microstructure,
- applied stress and
- the environment.

Therefore, avoidance of the problem may be achieved through appropriate material selection or by keeping the stress below the critical level for cracking. Where practicable, the environment may be modified although it is only occasionally possible.

7. Summary

Mirce-mechanics is a new discipline that studies the in-service life of maintainable systems through the sequence of functionability events taking place along the time axis.

Fully aware that the future in-service life of maintainable system cannot be improved by doing better statistics on the recorded data related to the past in-service life, the Mirce™ Science Laboratory set to collect the physical evidence about the mechanisms that drive system in-service process and originate functionability events.

Having collected the "physical evidence" about the events in the system in-service process the MIRCE Akademy set up a very detailed research programme with the objective of understanding the mechanisms and processes

In order to understand in-service processes it is necessary to understand their physical causes, and that represented a real challenge. In sense, what is the real cause of say, fatigue, the wind direction change, suncups formation on the blue ice runway, faulty weld, bird strike, perished rubber, maintenance induced error, carburettor icing, to name just a few.

After a numerous studies, discussions and trials, it has been concluded that any serious studies in this direction have to start at the "bottom end" of the physical world, namely with the atom system and to finish at the "top end" of the physical world, the solar system. This range is the minimum sufficient "physical scale" which enables the understanding of system in-service cause-effect relationships and provides enough information for the accurate predictions to be made. In other words, this is the physical range within which, the system functionability events mentioned above (fatigue, the wind direction change, suncups formation on the blue ice runway, bird strike, perished rubber, carburettor icing) take place and could be understood.

The rules, algorithms and methods developed by the Mirce-mechanics should enable the accurate predictions related to the in-service life of maintainable systems to be made. However, analysis and research performed in any "smaller scale" could lead to prediction errors

Further more, by applying the knowledge of Mirce-mechanics during the System Engineering Process it becomes possible to assess the in-service life of design of each design alternative, at the time when a constructive course of action could be taken. This could provide a considerable reduction in testing time, data collecting activities and modifications, which in turn could provide a considerable reduction in development cost and in-service risk.

8. Reference:

[1] Knezevic, J., *Mirce-mechanics*, Founders Lecture, Mirce Akademy, November 1999Woodbury Park, Exeter, UK.

[2] Knezevic, J., System In-service Success – Luck or Knowledge, Proceedings 7. Medjunarodna Konferencija, Upravljanje Kvalitetom i Pouzdanoscu, DQM, Belgrade, Serbia, 16-17 June 2004.

[3] Dubi, A., System Engineering Science, pp168, Mirce Science, Exeter, Great Britain, 2003,
ISBN 1-904848-00-1.

[4] Callister, W.D., Materials Science and Engineering – an Introduction, 4th edition, pp 856, John Wiley & Sons, New York, 1997. ISBN 0-471-13459-7
[5] Cosgrove, B., The World of Weather, Swan Hill Press, 1997, ISBN 1-84037210-9.
[6] Uvarov, E.B., and Isaacks, A., Dictionary of Science, Penguin, 1993, ISBN 0-14-0512662-4
[7] Ponomarev, L.I., The Quantum Dice, pp 251, Institute of Physics Publishing, 1993, Bristol, UK, ISBN 0-7503-0241-0
[8] Petrosky, H., To engineer is Human, The role of Failure in Successful Design, pp 252, Vintage Books, 1992, New York, USA, ISBN 0-679-73416-3
[9] Encyclopedia Britannica, Millennium Second Edition, CD-ROM
[10] Centre for Astrophysical Research in Antarctica, CARA, website
[11] Pesic, Seeing Double, pp 128, MIT, 2003 USA.

Physical Reality of Mirce-mechanics- Part 2: Natural World

Dr J. Knezevic,
MIRCE Akademy, Woodbury Park, Exeter, EX5 1JJ, UK

Abstract

This paper provides an introduction to the Mirce-mechanics, a new discipline that studies the in-service behaviour of in-service life of maintainable systems in order to develop methods for the prediction of their functionability performance. The in-service life is viewed as a sequence of occurrences of functionability events that are taking place in the time domain. The main argument provided here is that successful prediction can be achieved only by understanding the mechanisms that drive physical processes, which generate the occurrence of functionability events. In this paper the mechanisms that cause the occurrences of negative functionability events that originate from the natural world have been addressed and analysed. Also, the natural environment that souring most maintainable systems has been briefly analysed in order to familiarise the members of their design teams with daily natural environment of their systems. Also, the impact of that environment on the occurrences of the negative functionability events has been analysed and illustrated with several "real life examples".

1. Introduction

Humans have ability to know things, i.e., the faculty of creating links between them and establishing a chain of cause and effect. Different times in history saw different ways of realising these human capabilities. Our age is an age of science. We have become so used to identifying the concepts "knowledge" with "science" that we cannot conceive any other knowledge than scientific knowledge.

The essence of the scientific method can be explained quite simply. The method enables knowledge about phenomena to be obtained that can be checked, stored and passed on to other generations. It follows that science does not study phenomena in general, but only recurrent phenomena. It is mainly interested in seeking laws governing these phenomena.

Science has been created by humans for humans, and its ultimate purpose of all concepts is to explain and predict things that affect our senses or machines.

Science, as we know it today, started with Galileo, who is regarded as the father of experimental physics, and Newton who is the originator of theoretical physics. In their time, of course, physics was considered a united and indivisible science. In fact, there was not even physics as such for it was then called natural philosophy. However, this division is very significant. It enables us to bring out the two aspects of scientific method, namely, experiment and mathematics.

Science started when people learned to single out simple regularities from the chaos of available facts. It relies routinely on the analysis of facts and search for cause-effect relations, to find an eternal law, confirmed by another scientist by experiment.

The scientific method has transformed the world we live in. It has populated this world with machines, it has given sufficient food to people and protected them from diseases. Triumphs of the scientific method have engendered and strengthened a new faith – a faith in science. The change caused by scientific method in the minds of people is only comparable with such great religious concepts as Buddhism, Christianity, Islam and others. This all become possible due to a discovery that many things in nature can be described using numbers with equations establishing the relationships between them.

The power of science lies in its universality. Its laws are free from the arbitrariness of people; it only represents their collective experience, independent of age, nationality, rank, or frame of mind. It has a criterion of truth and its language does not contain the words “like” and “dislike”. In science truths are proved and phenomena are explained.

2 Mirce-mechanics

Mirce-mechanics is a new discipline that is defined by the author as the study of the in-service behaviour of maintainable systems. To make the clear different between the systems, whose life ends up, as far as designers are concerned, by delivering them to the customers, whose performance is measured through functionality performance, In Mirce-mechanics,: a set of components put together to deliver measurable functionality performance together with rules and actions required to maintain measurable functionability performance. It considers in-service life is a sequence of functionability events along the time axis. Its objectives are to:

- Understand physical processes and factors that determine the system in-service life,
- Generate rules and methods that analytically describe their functional relationships
- Systematically predict the in-service life of the system in time and space.

The word System is used as a generic term to represents all maintainable and managed products, constructions and organisations created to deliver function(s) with a measurable performance and attributes. The aggregate term for function, performance and attributes is functionability.

To deliver functionability in time domain all maintainable systems must engage in in-service processes that consist of the flow of operation, maintenance and support tasks. Successful execution of these in-service tasks, in time and space, ii connected with a necessary type and quantity of resources like personnel, equipment, facilities, tools, data and material.

In-service experience teaches us that irrespective of how good the maintainable system may be, interruptions in the provision of the functionability will occur during its life, caused by:

- inherent deficiencies of materials, design and production processes
- irreversible processes that take place in the system itself,
- interaction of the system with its in-service environment,
- planned execution of in-service and maintenance tasks
- insufficient in-service and maintenance resources.

However, the flow of the system functionability through its in-service time is not a deterministic process and cannot be treated with the same degree of certainty as the system's performance, weight and other physical characteristics. To deal with variability, inherent in the system itself and in its in-service interactions with natural, human and business environments, Mirce-mechanics draws on the concept of probability. The role of probability is to facilitate the prediction, as it is impossible to know exactly what sequence of events a in-service life of maintaainable system will consist of.

3. In-service Life of Maintainable Systems

In-service life of maintainable systems is a sequence of functionability events that take place in the time domain. Functionability events are occurrences that alter the in-service future of the system or cause the instant change of the state of the system. However, functionability events are direct consequences of the in-service processes that are taking place during the lifr of a system. Those processes could be internal or external to the maintainable system itself. Table 1 gives the list of observed in-service processes or events that the students, members of staff or Fellows of the Mirce Akademy have collected during an extensive period of research.

Table 1. Some of the observed processes/events that impact system in-service life

Lost concentration	Stressed operator	Software error	Frost damage
Expanded	Scored	Dirty	Parts missing
Air starved	Fused	Bogus part	Corroded
Overheated	Incorrect surface finish	Speeding	Incorrect wiring
Grooved	Maintenance error	Incorrect tension	Rotted
Oil saturated	Stretched	Undersized	Faded
Blocked	Bonding unsatisfactory	Smashed	Bird strike
Computer virus	Incorrect assembly	Twisted	Distorted
Shrunk	Incorrect rating	Faulty part	Torn
"Wrong snow"	Thunderstorm	Absent operator	Broken
Incorrect installation	Oversized	Contaminated	Fatigued
Software error	Vandalism	Head wind	Coalition
Transport damage	Battlefield damage	Drunk operator	Punctured
Spun off	Discoloured.	Run out of fuel	Melted
Seized	Typing error	Eroded	Perished

Poor electrical joint	Inspection	Incorrect focused	Damp
High/Low resistance	Shark bite	Weld defective.	Discouraged
Renewal	Replacement	Lubrication	Modification
Short circuit.	Incorrect adjustment	Scratched	Burnt
Power cut	"Too fine sand"	Bent	Charging
Communication error	Dented	Incorrect storage	Noisy
Head wind direction	Rodent attack	Blistered	Solar radiation
Calibration	Overhaul	Cleaning	Repair
Unbalanced	Incorrect drawing	Transport damage	Lost
Frayed	Adjustment	Testing	Bad weather

4. The Physical World

4.1 Solar System

The Solar System may seem enormous. In fact, it is only a small corner of the Universe. The Sun is a member of a vast group of stars called the Galaxy. All together, the Galaxy contains around 100,000 million stars. Distances are so great in astronomy that they have to be measured in light-years. Since light travels at $3x10^5$ kilometres per second it is obvious that we are dealing with bodies at incredible distances. On this scale, the Galaxy is 100,000 light-years across, and the Universe does not stop there. Scattered throughout space are millions of other galaxies. No one knows how big the Universe really is because it extends beyond the reach of our telescopes. However, these instruments have detected bodies that could be as much as 15,600 million light-years away. For comparison, the farthest distance that man has travelled into space, to the Moon, takes light a mere 1 ¼ seconds to cross.

However, the entire solar system contains only nine planets that move in elliptic paths around the Sun. All of them are lit by the Sun and do not produce their own light. The Sun's group of planets, together with their moons and other bodies, such as comets and asteroids is called the Solar System. The distance between the Sun and the Earth is $15x10^{10}$ metres (150 million kilometres) and the distance to its furthest member, Pluto, averages nearly $6x10^9$ kilometres.

Each second the Sun radiates $4.2x10^9$ kg of photons. The Earth receives only 0.0000000045 part of it, which is 1.85 kilograms. In the cold waste of cosmos it is less than 2 kilograms of photons per second that keep our planet green and warm. Owing to them rivers flow, winds blow, forest rustle and the human race flourishes. However, two kilograms of photons is not that small. From Einstein's formula $E=mc^2$ their energy of $1.7x10^{17}$ joules, which is $20x10^3$ times the power of the world's industry (about 10^{13} watts). About a half of that energy ($0.8x10^{17}$ watts) reaches the terrestrial surface, which is $5x10^{14}$ square metres in area, i.e. the average power of the solar radiation at ground level is 160 watts/m^2. The bulk of it, 99.9 %, is absorbed by the soil, and goes into the evaporation of water, causing winds, thunderstorms, and all that we loosely call weather. Thus, only 0.1 per cent of the radiant energy of the Sun (around 10^{14} watts) is captured by plants through photosynthesis of organic substances from carbon dioxide and water. It is this energy that supports all the living things on Earth, from bacteria to animals and human. [6]

The distance between the Sun and the Earth is $15x10^{10}$ metres (150 million kilometres).

4.2.1 The Planet Earth

The planet Earth is one of many "celestial bodies", but as it is so special to us we decided to a have a special name for it. In our daily conversations we call it - the world. Its radius is 6350 kilometres (3945.8 miles). Every day, the Sun crosses the sky, rising at dawn in the east and setting at dusk in the west. Night comes as the Sun moves beyond the horizon to the other side of the world and our side is shaded from its light. We say, for convenience, that the Sun crosses or moves in the sky, but it is, in fact, the Earth that is moving, and not the Sun. The Earth rotates once every 24 hours, spinning in a west-to-east direction but to anyone on the Earth's surface, the Sun appears to move from east to west. However, the length of day and night varies throughout the year. In summer, the days are long and nights short, while winter is a time of short days and long nights. These changes happen because the Earth's axis is tilted. The Earth's axis is an imaginary line about which the Earth rotates, it runs through the middle of the Earth from the North Pole to the South Pole. If this line were exactly at right angles to the plane of the Earth's orbit around the Sun, then all days and nights would be exactly the same length, 12 hours each, and there would be no seasons. But the axis is tilted at an angle of 23 ½°. As the Earth moves around the Sun in its orbit, first one pole tilts towards the Sun and then the other pole does. The earth's movement around the Sun thus causes seasonal changes in the world, creating a phenomenon, known as a climate.

When it is summer in the Northern Hemisphere, the North Pole is tilted towards the Sun, making the Sun appear to be high in the sky at midday. Days are long and it is warm, because the Sun's rays come straight down through the atmosphere and can heat the ground for a long time. At the same time, it is winter in the Southern Hemisphere. The South Pole is pointing away from the Sun, making the Sun appear to be low in the sky in the Southern Hemisphere. The days are short and nights long, and it is cold because the Sun's rays enter the atmosphere at a narrow angle and have little time to heat the ground. Six months later, the poles are pointing the other way and it is winter in the Northern Hemisphere and summer in the Southern Hemisphere. In between, spring and autumn occurs in each hemisphere. Then neither pole is tilted very much towards or away from the Sun. As a result, days and nights are about the same length during both the spring and autumn months.

4.2.3 The Atmosphere

The atmosphere of the earth is a thin spherical shroud composed of a mixture of gases and retained by gravitational attraction. It extends to a great height, but around 90% of the total mass of the air is found below 25 miles (40km). This thin layer of air makes life on earth possible.

The lowest layer of the atmosphere, the one in which humans live, is called the troposphere. The Greek word tropos means turning; turbulent air motion results in continual mixing, and the troposphere is host to much of what is called weather.

The air in the atmosphere is constantly circulating. It is like a vast system powered by the Sun. However, heat is unevenly distributed, the effect of the Sun being greatest at the Equator, where it passes directly overhead. As a result, there are great variations in air pressure, causing air currents (winds) to flow from high-pressure areas towards low-pressure areas.

At the Equator, air near the ground is heated, making it expand and rise. As a result, equatorial regions are characterised by a low-pressure air system, called the *doldrums.* On both sides of the Equator, air flows towards the doldrums in the trade-wind belts. The warm air rising above the equatorial zone cools as it ascends and spreads out north and south. Finally it sinks back to Earth around latitudes 30° N and 30° S, creating two high-pressure belts called the *horse latitudes.* At the surface, some of the descending air flows into the trade winds, and some flows towards the poles in a westerlies. They meet cold, dense air flowing from the poles along the polar front. The intermingling of warm, light, sub-tropical air with cold, dense polar air creates rotating low-pressure systems, called *depressions.* These bring changeable, stormy weather to middle latitudes.

This simple pattern of atmospheric circulation is complicated by several factors. First, because the Earth spins on its axis, winds do not flow north south, but are deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Winds are also deflected by mountain ranges. Another important factor is the seasonal development of large and fairly stable air masses. For example, the interiors of large mid-latitude continents heat up in summer. Large low-pressure air masses form into which winds are drawn. However, in winter, these continental interiors are cold, and so high-pressure air masses form, from which icy winds blow outwards.

4.3.4 The Weather

Weather is the day-to-day condition of the atmosphere. The chief items of weather are:

- the temperature and pressure of the air,
- wind speeds and directions,
- the amount of moisture in the air – particularly if the moisture is being precipitated as rain, snow, hail, sleet, dew or frost.

All air contains moisture in the form of water vapour, which is water in gaseous form. Warm air can hold more water vapour than cold air. When warm air is cooled, usually by moving upwards in the troposphere, its capacity to hold water vapour decreases. Finally, the condition is reached where the air is completely saturated, having a relative humidity of 100 per cent, known as *dew point.* Further cooling beyond dew point leads to water vapour condensing around nuclei, such as specks of dust or salt, to form water droplets or, in cold air, minute ice crystals. Large quantities of condensed water vapour form clouds.

There are two main kinds of clouds: cumuliform ('heap' clouds) and stratiform ('layer' clouds). Clouds are classified according to their height. Low clouds, within 1.5 miles (2.5 kilometres) of the surface, include: grey stratus; cumulus, a white heap cloud; cumulonimbus, a heap thundercloud; nimbostratus, a layer cloud often blurred by rain or snow; and stratocumulus, a greyish-white layer cloud. Medium-height clouds, from 1.55 to 3.7 miles (2.5 to 6 kilometres) are the greyish-white, rounded altocumulus, and the altostratus, which is a greyish layer cloud. Above 3.7 miles (6 kilometres) are the high clouds, including the feathery cirrus, cirrocumulus and cirrostratus.

Clouds form part of the water cycle, by which water is continually conveyed from the oceans to the land, where it is released from the air as precipitation. This provides the land with the fresh water needed by animal and plant life. Finally, the water completes the cycle by returning to the oceans.

Generally speaking there are three main kinds of rain:

- *Convectional,* which occurs, especially in the tropics, when hot air rises and water vapour condenses into towering, often anvil-topped cumulonimbus clouds. Inside the turbulent clouds, the water droplets collide, fuse together and fall as raindrops.

- *Cyclonic,* that takes place in depressions when warm air rises above wedges of cold air along cold and warm fronts and occlusions. In the middle latitudes, clouds contain super-cooled water droplets, which are still liquid although their temperature may be as low as -40°C and ice crystals. The ice crystals collide with super cooled droplets and grow in size. They then start to fall, melting near the surface to become raindrops or, if the air is cold, they then join together to form snowflakes, or even hail.

- *Orographic,* which result from the air rising over a mountain range.

Precipitation is a feature of storms. The commonest storms are thunderstorms, about 45,000 of which break out every day somewhere in the world. Thunderstorms occur when strongly rising air currents cause cumulonimbus clouds to form. As temperatures within the clouds fall, the outer shells of super cooled water droplets freeze and acquire a positive electrical charge. However, when the core subsequently freezes, it has a negative charge. The core expands as it freezes and shatters the outer shell, tiny splinters of which waft upwards, giving the top of the cloud a positive charge. The heavier cores remain lower down, building up a large negative charge. The air between the cloud and ground normally acts as an electrical insulator. But, when the charge on the cloud becomes great enough, the insulation breaks down and lightning – a gigantic spark – occurs. Along the lightning's path, heat causes a violent expansion of the air, and the resultant compression wave is heard as thunder.

Other storms include large, rotating hurricanes, also called tropical cyclones. Hurricanes strike the coasts of Central America and the south-eastern United States about 11 times per year. They cause much damage. Especially because strong winds hurl high waves onto the shore, causing flooding. Tornadoes are smaller, measuring about 500 metres across. Wind speeds in these rotating, funnel-like columns of air may reach 400 mph (650 km/h).

Weather satellites orbiting the Earth help forecasters to track hurricanes and give warnings of their advance, besides supplying much other information. At surface weather stations, on land and at sea, meteorologists take regular measurements of air conditions, including temperature, pressure, precipitation, and wind speeds and directions. Information about conditions in the upper air is provided by radio sondes – hydrogen-filled balloons carrying instruments.

Information from weather stations is sent to forecast centres, where it is often analysed by computers. Synoptic charts are prepared by summarising weather conditions over a large area. By comparing the latest synoptic chart with preceding charts, developments are noted. Meteorologists deduce how weather conditions will probably change and express them on a forecast chart, from which forecasts are made for the general public.

5. Natural World Induced Negative Functionability Events

As a part of the continuous observation of the behaviour of maintainable systems through in-service processes, the author has decided to collect the worldwide events that are relevant to Mirce-mechanics. Over the years, when new and relevant information was needed the author looked at the “loyal friend” named Aviation Weekly. In this “digital internet” driven world, Aviation Weekly, was providing fast and up to date information through their daily Aviation Weekly Bulletin service. Full text of the relevant events and processes is kept in the archive of the MIRCE Akademy, while a short statement about them is posted on the Akademy’s website[5] and shared with all interested parties, of course, free of charge.

- **12th June 2014 Unfavourable Winds Delay Test Flight of NASA's Low-Density Supersonic Demonstrator**: NASA is suspending efforts to test launch a disk shaped craft for the demonstration of technologies intended to greatly increase the payload mass that can be landed on the Martian surface, at the U.S. Navy’s Pacific Missile Range Facility, due to “two weeks of uncooperative wind conditions”. The announcement followed half a dozen attempts since June 3rd to launch the rocket powered Supersonic Inflatable Aerodynamic Decelerator from a high altitude balloon. The NASA team studied wind data in the region from 2012-13 and 2008-09 that suggested early June was favourable for the test flight. However, the weather pattern in the Northern Hemisphere changed this year, leading to a longer winter and unfavourable winds in the region. The test flight represents a major milestone for the $200 million, five-year old LDSD initiative managed by NASA’s Space Technology Mission Directorate. Current technologies

[5] ttp://www.mirceakademy.com/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=15&cntnt01returnid=15

support Martian landings with masses of about one ton. A human mission of the type NASA envisions for the 2030s would require a 40 ton capability.

- **25th July 2014: MD-83 Wreckage Found in Mali:** Near the border of Burkina Faso, the wreckage of Air Algerie Flight 5017 (AH5017) has been found in a "disintegrated state". Contact with the MD-83, operated by Spanish wet-lease company Swiftair on behalf of Air Algerie, was lost on the morning of 24th July, just 50 minutes after take-off from Ouagadougou en route to Algiers, just as air traffic control advised the aircraft to change course due to extreme weather conditions over Africa. There were 117 passengers and 6 crew members on board. Reports suggest that the aircraft broke up only upon impact with the ground, rather than in mid-air.

- **28th December 2014 – Air Asia Airbus A320 crashes in the Java Sea:** Z8501, a flight operated by Indonesia Air Asia, was en route from Surabaya, Indonesia, to Singapore early in the morning of Dec 28th. The aircraft, an Airbus A320-200, was flying around 120 nm southeast of Belitung Island when the crew requested to climb from Flight Level 320 (32,000 ft.) to FL380 and deviate from its planned track to avoid severe weather. Air Nav Indonesia approved the request, at least partially, but is reported to have cleared the aircraft only to FL340 initially to avoid traffic. When air traffic control cleared the aircraft to the new altitude, at 6:14 a.m. local time, QZ8501 did not respond. The aircraft disappeared from radar at 6:18 a.m. Wreckage and bodies found in the Java Sea off the Indonesian part of Borneo on Tuesday have been confirmed by Indonesian authorities to be from the missing Airbus A320, delivered to Air Asia in 2008. It was registered as PK-AXC. There were 155 passengers, two pilots, four flight attendants and one aircraft engineer on board. The captain had accumulated 20,537 flight hours, 6,100 of which were with Air Asia Indonesia on the A320 fleet. The first officer had 2,275 flight hours with the airline.

- **26th January 2015: Airlines Cancelled 1,900 U.S. Flights as Storm Hits Northeast:** Air travel to New York is being slashed as carriers scrap thousands of U.S. flights to keep planes, crew and passengers out of the path of a blizzard threatening the Northeast with as much as 2 ft. of snow. New York's three airports: LaGuardia, Kennedy and New Jersey's Newark Liberty, are feeling the brunt of the schedule changes. Airlines eliminated about half of Monday's arrivals at the trio of hubs, which make up the busiest U.S. travel market, while departures were cut by more than a third. Preliminary cancellations in the face of foul weather help carriers in part by relocating aircraft to unaffected airports. That positions airlines to resume service faster once flight conditions improve.

- **2nd March 2015: USAF Weather Satellite Explodes After Thermal Spike:** The U.S. Joint Space Operations Center is tracking a debris field of 43 objects after a weather satellite launched in 1995 apparently exploded. United States National Oceanic and Atmospheric Administration operators detected a sudden thermal spike in the Air Force Defence Meteorological Satellite Program Flight 13 (DMSP-13)], which was followed by an unrecoverable loss of altitude control," on Feb 3rd at 4:39

a.m. EST. (Space News was first to report the event.) Originally launched by the Air Force, DMSP satellites operate in polar orbit about 458 mi. over Earth, collecting a variety of weather data. A decision was made to "render the vehicle safe" and shift a dying satellite into a disposal orbit to avoid collisions of 43 debris objects created by the explosion with other operational satellites. Source: http://aviationweek.com/space/usaf-weather-satellite-explodes-after-thermal-spike?NL=AW-05&Issue=AW-05_20150303_AW-05_67&YM_RID

- **4th March 2015: Turkish Airline jet skidded in Nepal:** A Turkish Airlines jet that skidded off a slippery runway while landing in dense fog is seen at Tribhuwan International Airport in Kathmandu, Nepal .The plane with 238 people on board was coming from Istanbul when the accident happened. Officials say passengers had bumps and bruises but no serious injuries. The plane with 238 people on board was coming from Istanbul when the accident happened. Officials say passengers had bumps and bruises but no serious injuries.

- **29th March 2015: Air Canada A320 skidded upon Landing at Halifax:** Environment Canada issued a snowfall alert warning of low visibility in the eastern Canada. Air Canada flight AC624 from Toronto to Halifax "exited runway upon landing." The flight consisted of 5 crew and 133 passengers, 23 people were taken to hospital. The cause of the A320 coming off the runway hasn't been confirmed[6]. Information collected by Stuart Peake MFMA, from

- **16th April 2015: Throttle Valve Checks after Flawed Falcon 9 Recovery Attempt:** The Falcon 9 was seconds away from what would have been the first successful landing of a used booster stage on SpaceX's Autonomous Spaceport Drone Ship when the vehicle toppled over and was destroyed. The landing attempt occurred following the launch on April 14th of SpaceX's sixth cargo resupply mission to the International Space Station from Cape Canaveral Air Force Station, Florida. Video of the stage descending to the landing ship showed the vehicle approaching quickly but decelerating. However, closer to the platform the Falcon 9 showed an excessive horizontal velocity component that prompted the single engine used for landing to Gimbals to correct the flight path angle. The exhaust from the Merlin engine could be seen raising clouds of water from around the platform as the stage manoeuvred close to the edge of the landing zone. The control system then commanded vectoring of the engine nozzle to an angle that effectively over compensated for the previous flight path angle correction. By this time the vehicle was too low to make further corrections and landed at too great a tilt and speed to safely land. SpaceX is thought to be focusing on static friction in an engine throttle valve as the prime suspect for the loss of the Falcon 9 first stage during the third attempt at recovering the booster.

[6] http://www.straitstimes.com/news/world/americas/story/air-canada-jet-skids-halifax-runway-least-23-injured-20150329

- **30th April 2015: Bird Strike During Flight-test of Airbus A320neo:** While testing Pratt & Whitney PW1100G-powered A320neo MSN6101, fire was emitting from the core exhaust of the right-hand engine resulting from a bird strike. No details of the incident have been issued, but the position of the aircraft's flaps and transitioning main gear covers appear to indicate the A320neo was climbing out when the event took place. According to engine manufacturer the event is treated as if it was in service, which means that the replacement is processed using the standard support system of repair manuals and spare-parts distribution.

- **9th May 2015: Airbus A400M Crashes during Test Flight in Spain:** The Airbus A400M aircraft went down several minutes into a test flight before being delivered to Turkey, next month. Among the six people on the plane, all Spanish employees of Airbus, four were killed and two seriously injured, Airbus said. The accident occurred about 1 p.m. local time Saturday, 1 mile north of Seville's San Pablo Airport, which stayed closed while fire-fighters responded to the incident, but it was able to reopen during the early afternoon. As the aircraft took off from Runway 09, the crew immediately reported technical problems, which a German news outlet has described as multiple engine failures. The crew attempted to return to the airport's Runway 27, but the A400M struck electricity pylons before making a hard landing on agricultural land near an airport industrial estate. The engines are built by a consortium that includes Rolls-Royce Holdings Plc and France's Safran.

- **10th May 2015: MA60 Wing Detaches in Runway Excursion:** Flight JR1529 was operating the Yiwu-Fuzhou route when the aircraft, registered B3476, veered off the runway upon landing at Fuzhou Changle International airport. As a result the complete wing of an Avic MA60 turboprop airliner became partly detached then pivoted on the fuselage. Five people among the 45 passengers and seven crew members of the Joy Air aircraft suffered minor injuries. Photographs of the wrecked aircraft show failure of the centre wing box's rear attachments to the fuselage. With the wing-mounted landing gear still attached, the wing pivoted on its forward attachments. Hence, when the aircraft came to rest the wing, still complete from tip to tip, was at negative incidence to the forward fuselage, with the fronts of the engine nacelles resting on the grass. The MA60, seating 50-60 passengers, is an updated version of the Y-7, itself based on the Antonov An-24. Like the following MA600 version, it features Pratt & Whitney Canada PW127 engines and western avionics. Joy Air belongs to Avic, which became a carrier in 2008 to operate the MA60.

- **25th May 2015: Double Engine Failure of Airbus A330:** Singapore Airlines flight 836, from Singapore to Shanghai, suffered a double engine (Rolls-Royce Trent 772B turbofan) failure on May 25th. The Airbus A330-343 was flying through the outflow of a huge storm, just south of Hong Kong, when the incident occurred. The aircraft, with 182 passengers and 12 crew on board, dropped from 39000ft to 13000ft before power was restored. Despite being relatively close to Hong Kong the pilots decided to continue to Shanghai after restarting the engines. On the ground in

Shanghai the aircraft was tested but no faults were found. Singapore's air accident investigation bureau is looking into the incident[7].

- **29th July 2015: Hail Damaged Boeing 787 returns back to China:** American Airlines' Boeing 787 was climbing out of Beijing, China; when it encountered a hailstorm that left the 3 month old airplane somewhat beaten up. Flight 88 from Beijing to Dallas/Fort Worth Airport, DFW, was about 20 minutes out of Beijing and climbing above 26,000 feet when it began descending. It landed back at Beijing less than 45 minutes after takeoff. Once the necessary repairs to make the airplane airworthy are made in Beijing, the airplane will go to American's DFW maintenance base for more repairs and checks

- **30th July 2015: Dubai Airport Planning Camera-based Debris Detection:** To enhance the process of identifying and removing debris from runway areas, and improve flights safety, Dubai International Airport plans to begin using camera-based foreign object debris (FOD) detection system early in 2016. Current statistics shows that the airport's two parallel runways on average, experience one event in every 29,400 landings or takeoffs. While that number is down from the 1.14 FOD findings per 10,000 movements in 2010, the detection rate has been holding steady for the past three years as traffic continues to climb. The most significant event of FOD took place in 2010, when a high-speed rejected take off by an Emirates Boeing 777-200 occurred, after a nose gear tyre failure at more than 170 kt. beyond which pilots will generally continue a take off. In this case, the pilots applied full reverse thrust and braking and stopped the aircraft with 4,000 ft. of runway remaining. This even, enhanced FOD protection program that included training, visual inspection of operational areas, and FOD reduction programs and maintenance. The next reduction in FOD events is expected to come from an electro-optical and infrared FOD detection system that will provide real-time alerts when items less than 5 cm in diameter are spotted, with the location reported back to within 10 cm accuracy. Other airports are using similar technology, including an electro-optical and millimetre-wave radar FOD detection system at the Tel Aviv, Boston and Seattle-Tacoma airports.

- **12th August 2015: American Airlines Repaired Hailstorm-damaged B787:** The composite fuselage, one of the things that separate the Boeing 787 from most other airplanes, itself took no apparent damage on the July 27th hailstorm northeast of Beijing. The radome nose cone that protects the radar and other avionics on the airplane's front tip was hammered. It was replaced in Beijing with a spare radome that American Airlines flew over to Beijing airport. They also covered some small punctures on the wing's underside with speed tape, a strong, thin aluminium tape. The airplane was flown to Tokyo's Narita International Airport, where repair personnel replaced the side windscreens on the left and right sides, on August 2nd. The

[7] http://t.co/l0m3uoLds6 pic.twitter.com/IOjO2FujsN — Flightradar24 (@flightradar24).

windscreen's outer panes had cracked on their front edges and bottoms, but the inner panes were not damaged, and the integrity of the window was maintained throughout. Then, the airplane returned to Dallas/Fort Worth, American Airlines repair facilities, where major inspections started. Thus, 44 panels were removed and shipped to American's composite shop at its Tulsa composite repair centre maintenance base for repairs and repainting. Their large autoclave is to repair many of them at one time. Some curved aluminium pieces that form the wing's leading edge are also being replaced. American Airlines expects to put dinged-up Boeing 787 back in the air in next week.

- **16th August 2015: Indonesia's Trigana Air, ATR 42 Crashed:** The ATR 42-300, was flying from Jayapura on the northern coast of Papua to the inland town of Oksibil lost contact with air traffic control just before 3 p.m. local time. There were 54 people on the aircraft, comprising 49 passengers and 5 crew. The route was over a remote mountain range, bad weather and poor visibility were reported in the area. Wreckage believed to be from a missing aircraft has been located in mountainous terrain in the Papua region of Indonesia, on the island of New Guinea. Local villagers had earlier reported seeing wreckage. It is not yet known if there were any survivors.

- **19th March 2016: Fly Dubai Flight FZ981 Crash Landing Killing 62 People on the Board:** The final frames of imagery captured by several surveillance cameras of the Boeing 737-800 with 62 passengers and crew plunging into the ground in a steep nose-down attitude at the Rostov-on-Don Airport. It arrived in this area at approximately 2:00 a.m. local time after a 4-hr. flight from Dubai. The first attempt at the instrument landing system approach to Runway 22 ended with a missed approach initiated at more than 1,700 ft. above ground, well above the 480 ft. minimum. It is possible that wind shear conditions, which the approach chart states can be "expected on the final" arrival to the runway, may have played a role in the abort. Climb rates during the first go-around averaged about 2,250 ft. min. up to 8,000 ft., where the aircraft maneuvered in the local area for 25 min. FZ981 later climbed to 15,000 ft., where it held for nearly 1 hr. until attempting a second instrument landing to Runway 22 at approximately 3:30 a.m. On the recording, voices from the cockpit appear to be calm throughout the ensuing approach, informing the tower controller that the aircraft would climb to 8,000 ft. in case of another miss. The pilots reported being "established on the localizer," meaning the aircraft had locked in its lateral guidance on the ILS. As it descended through approximately 1,500 ft. however, the pilot radioed the tower, "Going around, 981."

6. Summary

Mirce-mechanics is a new discipline that studies the in-service life of maintainable systems through the sequence of functionability events taking place along the time axis.
Fully aware that the future in-service life of maintainable system cannot be improved by doing better statistics on the recorded data related to the past in-service

life, the author set to collect the physical evidence about the mechanisms that drive system in-service process and originate functionability events.

This paper provides an introduction to the Mirce-mechanics, a new discipline that studies the in-service behaviour of in-service life of maintainable systems in order to develop methods for the prediction of their functionability performance. The in-service life is viewed as a sequence of occurrences of functionability events that are taking place in the time domain. The main argument provided here is that successful prediction can be achieved only by understanding the mechanisms that drive physical processes, which generate the occurrence of functionability events. In this paper the mechanisms that cause the occurrences of negative functionability events that originate from the natural world have been addressed and analysed. Also, the natural environment that souring most maintainable systems has been briefly analysed in order to familiarise the members of their design teams with daily natural environment of their systems. Also, the impact of that environment on the occurrences of the negative functionability events has been analysed and illustrated with several “real life examples”.

8. Reference:

[1] Knezevic, J., *Mirce-mechanics*, Founders Lecture, Mirce Akademy, November 1999Woodbury Park, Exeter, UK.
[2] Knezevic, J., System In-service Success – Luck or Knowledge, Proceedings 7. Medjunarodna Konferencija, Upravljanje Kvalitetom i Pouzdanoscu, DQM, Belgrade, Serbia, 16-17 June 2004.
[3] Dubi, A., System Engineering Science, pp168, Mirce Science, Exeter, Great Britain, 2003, ISBN 1-904848-00-1.
[4] Cosgrove, B., The World of Weather, Swan Hill Press, 1997, ISBN 1-84037210-9.
Bristol, UK, ISBN 0-7503-0241-0
[5] Centre for Astrophysical Research in Antarctica, CARA, website
[6] Ponomarev, L.I., The Quantum Dice, pp 251, Institute of Physics Publishing, 1993, Bristol, UK, ISBN 0-7503-0241-0

Physical Reality of Mirce-mechanics- Part 3: Human World

Dr J. Knezevic,
MIRCE Akademy, Woodbury Park, Exeter, EX5 1JJ, UK

Abstract

This paper provides an introduction to the Mirce-mechanics, a new discipline that studies the in-service behaviour of in-service life of maintainable systems in order to develop methods for the prediction of their functionability performance. The in-service life is viewed as a sequence of occurrences of functionability events that are taking place in the time domain. The main argument provided here is that successful prediction can be achieved only by understanding the mechanisms that drive physical processes, which generate the occurrence of functionability events. In this paper the mechanisms that cause the occurrences of negative functionability events that originate from the human world, has been addressed and analysed. Also, the human world that is inevitable part of the maintainable systems has been briefly analysed in order to familiarise the members of their design teams with their particular characteristics that are very different from the technical world familiar to mechanical, electrical, aeronautical and other types of engineers. Also, the impact of human actions on the occurrences of the negative functionability events has been analysed and illustrated with several "real life examples".

1. Introduction

Humans have ability to know things, i.e., the faculty of creating links between them and establishing a chain of cause and effect. Different times in history saw different ways of realising these human capabilities. Our age is an age of science. We have become so used to identifying the concepts "knowledge" with "science" that we cannot conceive any other knowledge than scientific knowledge.

The essence of the scientific method can be explained quite simply. The method enables knowledge about phenomena to be obtained that can be checked, stored and passed on to other generations. It follows that science does not study phenomena in general, but only recurrent phenomena. It is mainly interested in seeking laws governing these phenomena.

Science has been created by humans for humans, and its ultimate purpose of all concepts is to explain and predict things that affect our senses or machines.

Science, as we know it today, started with Galileo, who is regarded as the father of experimental physics, and Newton who is the originator of theoretical physics. In their time, of course, physics was considered a united and indivisible science. In fact, there was not even physics as such for it was then called natural philosophy.

However, this division is very significant. It enables us to bring out the two aspects of scientific method, namely, experiment and mathematics.

Science started when people learned to single out simple regularities from the chaos of available facts. It relies routinely on the analysis of facts and search for cause-effect relations, to find an eternal law, confirmed by another scientist by experiment.

The scientific method has transformed the world we live in. It has populated this world with machines, it has given sufficient food to people and protected them from diseases. Triumphs of the scientific method have engendered and strengthened a new faith – a faith in science. The change caused by scientific method in the minds of people is only comparable with such great religious concepts as Buddhism, Christianity, Islam and others. This all become possible due to a discovery that many things in nature can be described using numbers with equations establishing the relationships between them.

The power of science lies in its universality. Its laws are free from the arbitrariness of people; it only represents their collective experience, independent of age, nationality, rank, or frame of mind. It has a criterion of truth and its language does not contain the words “like” and “dislike”. In science truths are proved and phenomena are explained.

2 Mirce-mechanics

Mirce-mechanics is a new discipline that is defined by the author as the study of the in-service behaviour of maintainable systems. To make the clear different between the systems, whose life ends up, as far as designers are concerned, by delivering them to the customers, whose performance is measured through functionality performance, In Mirce-mechanics,: a set of components put together to deliver measurable functionality performance together with rules and actions required to maintain measurable functionability performance. It considers in-service life is a sequence of functionability events along the time axis. Its objectives are to:

Understand physical processes and factors that determine the system in-service life,
Generate rules and methods that analytically describe their functional relationships
Systematically predict the in-service life of the system in time and space.

The word System is used as a generic term to represents all maintainable and managed products, constructions and organisations created to deliver function(s) with a measurable performance and attributes. The aggregate term for function, performance and attributes is functionability.

To deliver functionability in time domain all maintainable systems must engage in in-service processes that consist of the flow of operation, maintenance and support tasks. Successful execution of these in-service tasks, in time and space, ii connected with a necessary type and quantity of resources like personnel, equipment, facilities, tools, data and material.

In-service experience teaches us that irrespective of how good the maintainable system may be, interruptions in the provision of the functionability will occur during its life, caused by:

- inherent deficiencies of materials, design and production processes
- irreversible processes that take place in the system itself,
- interaction of the system with its in-service environment,
- planned execution of in-service and maintenance tasks
- insufficient in-service and maintenance resources.

However, the flow of the system functionability through its in-service time is not a deterministic process and cannot be treated with the same degree of certainty as the system's performance, weight and other physical characteristics. To deal with variability, inherent in the system itself and in its in-service interactions with natural, human and business environments, Mirce-mechanics draws on the concept of probability. The role of probability is to facilitate the prediction, as it is impossible to know exactly what sequence of events a in-service life of maintainable system will consist of.

3. In-service Life of Maintainable Systems

In-service life of maintainable systems is a sequence of functionability events that take place in the time domain. Functionability events are occurrences that alter the in-service future of the system or cause the instant change of the state of the system. However, functionability events are direct consequences of the in-service processes that are taking place during the lifr of a system. Those processes could be internal or external to the maintainable system itself. Table 1 gives the list of observed in-service processes or events that the students, members of staff or Fellows of the Mirce Akademy have collected during an extensive period of research.

Table 1. Some of the observed processes/events that impact system in-service life

Lost concentration	Stressed operator	Software error	Frost damage
Expanded	Scored	Dirty	Parts missing
Air starved	Fused	Bogus part	Corroded
Overheated	Incorrect surface finish	Speeding	Incorrect wiring
Grooved	Maintenance error	Incorrect tension	Rotted
Oil saturated	Stretched	Undersized	Faded
Blocked	Bonding unsatisfactory	Smashed	Bird strike
Computer virus	Incorrect assembly	Twisted	Distorted
Shrunk	Incorrect rating	Faulty part	Torn
"Wrong snow"	Thunderstorm	Absent operator	Broken
Incorrect installation	Oversized	Contaminated	Fatigued
Software error	Vandalism	Head wind	Coalition
Transport damage	Battlefield damage	Drunk operator	Punctured

Spun off	Discoloured.	Run out of fuel	Melted
Seized	Typing error	Eroded	Perished
Poor electrical joint	Inspection	Incorrect focused	Damp
High/Low resistance	Shark bite	Weld defective.	Discouraged
Renewal	Replacement	Lubrication	Modification
Short circuit.	Incorrect adjustment	Scratched	Burnt
Power cut	"Too fine sand"	Bent	Charging
Communication error	Dented	Incorrect storage	Noisy
Head wind direction	Rodent attack	Blistered	Solar radiation
Calibration	Overhaul	Cleaning	Repair
Unbalanced	Incorrect drawing	Transport damage	Lost
Frayed	Adjustment	Testing	Bad weather

4. The Physical Reality

4.1 Human World

All modern men and women, therefore, belong to the species *Homo sapiens*. And so, scientifically, all people belong to one race, the human race. However, people display differing physical features, including skin colour, eye and hair colour, skull shapes, height and build. Anthropologists have devised various methods of classifying mankind, but it is generally accepted that there are three broad sub-groups. They are, in order of population size, the 'white-skinned' Caucasoids, the 'yellow-skinned' Mongoloids and the 'black-skinned' Negroids.

The human world is also divided in accordance to the following criteria:

- Languages: There are nearly 2,800 languages, not including dialects. Some languages, such as those spoken by small groups in Africa and the Amazon basin, are spoken only by a few thousand people. Others, such as Chinese and English, are used by millions. A few languages have achieved international importance. The languages most used in international business are English, French and German, which together are used for about four-fifths of all business transactions. These languages have spread around the world, partly because of migration and colonisation and partly because the countries in which these languages are spoken are among the world's foremost trading nations. Other languages that have spread widely from their original area are Spanish and Portuguese, specially throughout South America. Russian, Italian and Arabic. Chinese is of major importance in terms of number of people who speak it, but this language is of minor importance in international business.

- Religions: Most religions combine the worship of one or several gods with ethical rules of conduct, although some are chiefly ethical and philosophical.

There are 10 major religions; Christianity, Islam, Hinduism, Confucianism, Buddhism, Shinto, Taoism, Judaism, Sikhism and Jainism.

Human population is around 7 billion people. Most of the growth is expected to take place in developing nations. The density of the population is 12.6 per km² (by total area) and 43.1 per km² (by land area). The age and sex rations are shown in the table below:

Age structure	Total	Male	Female
0 to 14 years	29.9 %	15.4 %	14.6 %
15 to 64	63.2 %	32.0 %	31.2 %
65 and over	6.9 %	3.0 %	3.9 %

Life expectancy at birth, for the total population: 64 years, (male: 62 years and female: 65 years). Total fertility rate: 2.8 children born/woman (2000 est.)

5. Human Performance in Maintainable Systems

In order to understand and use task maintenance analysis it is necessary to first understand human performance. Advanced maintainable systems consist of hardware, software and personnel. These components act together to accomplish some mission or output goal. The accomplishment of an output goal depends on a number of variable that represent system functions. In other words, system functions are activities that control the variable that influence the goal output of a system.

System functions may be executed by personnel or by hardware-software components of the system, but often involve both. Personnel performance requirements in function execution depend on the degree of automation of the system. At the lowest level there is no automation, only mechanisation: personnel directly control the hardware and monitor its performance parameters and results by means of displays of sensor outputs, by direct perception, or buy a combination of these. As automation increases the "machine" is increasingly able to control its own performance (eg to maintain a functional parameter at a given value without human involvement; or a t a higher level, to maintain several parameters in proper relationship; or at a still higher level, to alter controls schemes to optimize parameter relationship across functions for different modes and conditions of operation).

With higher levels of automation, human performance requirements become increasingly supervisory in nature. Personnel verify, monitor and evaluate the execution of system functions by the hardware and software constituents, and adjust and co-ordinate their performance as required to safeguard the system and maintain productivity.

The human constituents of a system bear the ultimate responsibility for recognising, interpreting, compensating for, and correcting or mitigating the consequences of deficiencies, failures and malfunctions in the hardware and software and in their own performance. Thus "human error" or "judgement error" are terms found frequently in reports on system failures. In many cases, however, system failures can be attributed to the poor design of tasks for human capabilities, to defective interfaces between task performers and equipment subsystems, to inadequate training, to poorly conceived operating or maintenance procedures, or to other situational factors. In-depth investigation and analysis of accidents and injuries provide proof that often inadequate attention is given to describing, evaluating and facilitating the human performance required by the system.

The broad objective of task analysis is to meet these needs. Human error cannot be completely eliminated by systematic forecasting, description, and analysis of human tasks during system development, not by the evaluation of actual task performance during system test and evaluation, abut such an effort can go a long way to achieving system designs that make the best use of human capabilities, provide adequate margins of safety, and are more effective in achieving system goals economically.

6, Impact of Human World on Maintainability Systems

Human beings are an irreplaceable part of any maintainable system, Given the major contribution of human behaviour to the failures, accidents and other functionability events that take place during the operation, maintenance and support processes, over the last hundred years an enormous amount of research has been conducted in human physiology and psychology. It is commonly accepted that the processes taking place in the human mind and their interactions with the human's physiological functions are extremely complex. A number of facts have been established but many theories still exist which have to be proven or discarded.

One of the main research topics undertaken at the MIRCE Akademy are to studies the maintenance process, which is a highly error-productive process. It witnesses a large- proportion of human factors problems in a wide range of hazardous technologies. However, human errors in maintenance fall into systematic patterns relating, to both the nature of the activity and the types of error involved. There is considerable evidence to show that re-assembly and installation are associated with the major share of the human errors made. In addition, omissions, failing to carry out necessary actions, usually when putting things back, make up the largest single category of maintenance errors. Finally, most of these errors have been judged by experienced maintenance engineers as having happened before - and are seen as likely to happen again. The fact that the same errors keep on happening to different people in different organisations strongly suggests the need to focus remedial attention more upon the task and the workplace than upon the presumed psychological inadequacies of those making the errors.

As a part of the continuous observations of the behaviour of maintainable systems through in-service processes, the author has decided to collect the worldwide functionability events that are relevant to Mirce-mechanics. All of the examples presented below are from Aviation Weekly and Space Technology. Full text of the relevant events and processes is kept in the archive of the MIRCE Akademy, while short descriptions of them are presented here, thus:.

- **12th June 2014 Unfavourable Winds Delay Test Flight of NASA's Low-Density Supersonic Demonstrator**: NASA is suspending efforts to test launch a disk shaped craft for the demonstration of technologies intended to greatly increase the payload mass that can be landed on the Martian surface, at the U.S. Navy's Pacific Missile Range Facility, due to "two weeks of uncooperative wind conditions". The announcement followed half a dozen attempts since June 3rd to launch the rocket powered Supersonic Inflatable Aerodynamic Decelerator from a high altitude balloon. The NASA team studied wind data in the region from 2012-13 and 2008-09 that suggested early June was favourable for the test flight. However, the weather pattern in the Northern Hemisphere changed this year, leading to a longer winter and unfavourable winds in the region. The test flight represents a major milestone for the $200 million, five-year old LDSD initiative managed by NASA's Space Technology Mission Directorate. Current technologies support Martian landings with masses of about one ton. A human mission of the type NASA envisions for the 2030s would require a 40 ton capability.

- **23rd June 2014: Fire on Board of F-35A:** During the preparation for a training mission of an F-35A fire was detected in the aft end of the single-engine, stealthy fighter. Emergency responders, at Eglin Air Force Base in Florida, USA, used foam to extinguish the fire. The cost of the damage to the aircraft is likely to be the first F-35 class a mishap, which is an event where an aircraft sustains more than $2 million in damage or results in a fatality, as the fire is thought to have badly damaged the Pratt & Whitney F135 engine. The event is under investigation.

- **17th July 2014: Malaysia Airlines Flight MH17 Shot Down:** A Boeing 777- 200ER registered 9M-MRD en route from Amsterdam to Kuala Lumpur, crashed Thursday 30km from the Tamak waypoint, about 50km from the Russia-Ukraine border. There were 283 passengers and 15 crew on board. The flight was operated as a code-sharing service with KLM Royal Dutch Airlines. The aircraft was cruising at 33,000 ft. and at a speed of 476 knots. It left Amsterdam at 1215 and was due to arrive in Kuala Lumpur at 0600 local time on Friday. There were no survivors.

- **16th October 2014: Solar Power Channel Repair of the International Space Station:** Two NASA astronauts successfully replaced a failed sequential shunt unit on solar power channel that has been shut down since May 8th. They spacewalked from the far starboard to the far port side of the station's near 360-foot-long solar power truss. During the repair the astronauts encountered several balky bolts, which threatened to slow or interrupt an ambitious list of secondary tasks. Also, they battled the difficulties with a combination of power and hand tools to restore an ISS by an internal short and then clear the path for external reconfigurations next year that will accommodate a pair of docking ports for new Commercial Crew Program spacecraft. Source: http://aviationweekly.com/blog

- **22nd October 2014: 218 minutes of Functionability Actions on the International Space Station:** To maintain the functionability of International Space Station two Russian astronauts successfully performed several functionability tasks. During the first outing they removed a protective cover from a European science experiment that exposes seeds, bacteria spores, fungi, ferns and other samples to the harsh environment of space. The second spacewalk was conducted to disconnect and discard two obsolete antennas that used to guide visiting spacecraft to docking ports. They will remain in orbit for up to a year before, when pulled by the Earth's gravity they will be incinerated in the atmosphere.

- **8th December 2014: Light Jet Crashed near the airport in Washington D.C. Area:** In 2009 a built light jet Embraer Phenom 100, crashed near an airport in the Washington, D.C area. It has been confirmed that three people on the aircraft as well as three people in a house that burned down as a result of the crash were killed. Eye witnesses described the aircraft as flying very low with motion that could indicate a stall-like condition. The pilot did not make any distress calls before the accident. Airport officials had been warning other pilots in the traffic pattern of a large amount of bird activity in the vicinity of the runway end.

- **14th January 2015: Astronauts Forced to Abandon Part of ISS:** At about 4 a.m. International Space Stations systems indicated that measurements of ammonia in the cabin appeared to be off-scale and all six astronauts quickly donned masks and ordered to evacuate into Russian segment. Once it was confirmed to be clear of ammonia, they were permitted to remove their masks. After reviewing data in Houston, teams told the astronauts to return to the American segment, but an increase in pressure, possibly from ammonia entering the cabin, forced the crew to once again don masks and seal themselves in the Russian segment. The International Space Station's cooling system features ammonia in its loops on its exterior that transfer heat from the inside. Because ammonia is toxic, water is used inside to transfer the heat to the ammonia loops on the outside.

- **19th February 2015: NASA delays space station space walk because of suit issue:** A series of planned space walks at the International Space Station will be delayed, as a result of a spacesuit investigation. Two critical fan and pump units for the astronauts' spacesuits failed recently during routine maintenance in orbit. Engineers suspect water seeped into the bearings, causing them to corrode and seize up. Both units were returned to Earth on the Dragon capsule last week. The spacesuits that will be used for the spacewalks have check out fine. NASA says a pump failure would cut short a spacewalk, but not endanger anyone. An unrelated problem with the same component led to an astronaut's near-drowning in 2013.

- **19th March 2015: Lufthansa Technik's Robot-based Inspection of Engine Components:** Based on the principle of white light interferometry (WLI), the goal of the Lufthansa' Auto Inspect research project is to generate digital geometry and damage information to be used for robot based automated inspection process chain and is aimed to fully automated detection procedures for combustor components of jet engines. The interference effect of light waves is used to conduct a high-resolution scan of the component surface, with this optical measurement procedure. Lufthansa Technik has filed an international patent for this technology. Currently, this type of repair and inspection uses a multi-stage, energy intensive and sometimes ecologically harmful inspection process. It is expected that this automation will mitigate cost and increase quality by transforming the process to one automated 'clean' process step. Source: Regina Kenney AviationWeek.com

- **24th March 2015: Germanwings A320 Reached Ugly State in French Alps:** German wings flight 4U 9525, with 150 people on board, from Barcelona at 10:01 a.m. reached its cruising altitude of 38,000 ft. at 10:27. Its last air traffic control (ATC) contact took place at 10:30 a.m. and was a routine communication that cleared the aircraft for the IRMAR waypoint around 25 nm south of Barcelonnette, France. One minute later the aircraft began its unexpected descent, losing approximately 30,000 ft. in altitude in 8 min, which was a steep drop, but well within the aircraft's normal flight envelope. The last recorded altitude was 6,175 ft., slightly higher than where the aircraft reached the ugly functionability state by crashing into a mountain. There were no survivors.

- **24th March 2015: Near Loss of U.K. A330 due to Positioning of Captain's Personal Camera:** The report published by the Military Aviation Authority describes how the Airbus A330-200 Voyager multi-role tanker transport came close to being lost with all 198 passengers and crew on-board. The event took place during a trooping flight to Afghanistan on Feb 9th last year at 33,000 ft. over the Black Sea. The captain was alone on the flight deck as the co-pilot took a break. During this time, the captain took 28 photos of the flight deck using his personal digital before placing the camera between the captain's seat arm rest and the left-hand side-stick controller. One minute before the incident, the captain moved his seat forward, creating a slight physical jam between the arm rest and the side-stick, which had the camera wedged between them forcing the side-stick fully forward and initiating the pitch-down command. The stick command disconnected the autopilot and sent the aircraft into a steep dive, losing 4,400 ft. in 27 sec. With no co-pilot in the right-hand seat, the command could not be countermanded. The aircraft's on-board self-protection systems overrode the stick input, with pitch-down protection activated 3 sec. after the pitch-down command was given, while high-speed protection was triggered 13 sec. after the event started as the aircraft passed through 330 kt. With the flight control system idling the engines, it recovered the dive to level flight. Report states that the camera became free from the side-stick and armrest after 33 sec. During the action in the cockpit, passengers and crew in the cabin were thrown to the ceiling, with 24 passengers sustaining injuries during the dive, along with all seven of the cabin crew. Most of the injuries occurred as the individuals hit the ceiling and overhead fittings or were struck by loose objects. The flight was diverted to Incirlik air base in Turkey, where it safely landed. Although the event caused damage to a number of fixtures and fittings inside the cabin, there was no damage to the cockpit and no structural damage to the aircraft.

- **6th April 2015: First Great Western train driver takes wrong train & goes wrong way:** A train driver and train manager boarded a service in Banbury Oxfordshire intending to take passengers to London

Paddington. Instead the train crew got on a train heading to Swansea in South Wales and proceeded to make the journey. The mistake was realised after a short time, the simplest solution was to return the train crew to Banbury to collect the correct train. The service to Swansea and the service to London Paddington each incurred a half hour delay. Information collected by Stuart Peake, Master Fellow of the MIRCE Akademy from the Huffington post, UK.

- **12th May 2015: 4 hour delay due Transportation Security Administration agents having gone home:** Spirit Airlines flight 332 was due to leave Atlantic City for Boston at 5pm on the 12th May 2015, bad weather delayed the pilot and the first officer arriving at the airport so boarding didn't commence until 8pm. A further delay was incurred as there were no TSA personnel available to process the pilots. "The gate agent who came onto the plane with an update said the pilots are on their way but they can't get to the plane because there's nobody at TSA to process them. The TSA folks had gone home, so they were waiting for somebody to come back to the airport from TSA. How can Atlantic City airport be without a TSA presence when there are still people there? The Spirit Airlines did confirm that the "TSA had closed operations but reopened at Spirit's request and the crew was able to make the flight." and that passengers were allowed off the aircraft while they waited for the crew to arrive. D'Angeleo said he arrived in Boston about 4 hours behind schedule. Information collected by Stuart Peake, Master Fellow of the MIRCE Akademy, Original Article flightclub.jalopnik.com | May 12 10:26 AM

- **29th May 2015: Falsified Records for Used CFM56 Engine Blades:** CFM International has discovered several cases of parts brokers are offering used CFM56 high-pressure turbine (HPT) blades with falsified records that misrepresent the parts' service histories. The most-recent alert added an eighth set to seven flagged alerts earlier in the year. In one case, CFM's own documentation showed that a set of blades had 31,000 hr. and 4,207 cycles at its engine's first shop visit in 2006. The allegedly current paperwork now accompanying the blades lists just 2,600 hr. and 482 cycles since the parts entered service. In other cases GE and CFM found myriad anomalies, including "engine-data submittal" records sourced to CFM that did not match documents issued by the manufacturer; shop visit records attributed to both GE Engine Services and Snecma that were not issued by the MRO providers; falsified airworthiness release forms; and records tracing the blades back to airlines that never operated them. The records-falsification efforts mixed sophistication with amateurism, GE paperwork sent to FAA shows. One set of shop records lists a real Snecma Services employee as an authorized approver, but the signature on the forms does not match the employee's verified signature. The same set of records uses the wrong Snecma Services logo. The documents also claim the blades in question were once installed on an engine operated by Aerolineas Argentinas, but GE verified through its own records that the engine serial number listed never flew on any of the carrier's aircraft. One suspected set consists of 80 blades, enough for one engine, and retails for about $1 million new. Source: Aviation Weekly Newsletter.

- **29th May 2015: A400M Crashed by Incorrectly Installed Engine Software:** Airbus Group revealed that incorrectly installed engine control software caused the fatal crash of an A400M airlifter in Spain on 9th May. Incorrect installation took place during final assembly of the aircraft, which led to engine failure and the resulting crash. The conclusion was based on the data extracted from the flight data recorder, which confirmed the Airbus engineer's internal hypothesis that there had been no problem with the aircraft. Of the five A400M operators, only France has continued flying its fleet of six aircraft. Germany, Malaysia, Turkey and the U.K. are still pausing flight operations.

- **15th June 2015: Heavy Fumes in Cabin Force Passengers out on Wing:** After the Allegiant Air flight 331 from Los Angeles to Boise landed heavy fumes began filling the cabin. The situation quickly escalated and passengers began to worry, especially as the flight crew offered little assistance or instruction, according to passengers. Hence, as the central aisle crowded with people desperate to get off the plane, vapour (believed to be smoke) began entering through the air vents, creating enough panic that passengers decided to take matters into their own hands and open the emergency exits and escape onto the wing. The plane had 163 passengers and six crew members on board. 'Passengers on Flight 331 have been issued $50 vouchers for future travel. The plane involved was a MD-80, a twin-engine commercial jet.

- **30th June 2015: Man Commits Suicide in Japan Bullet Train:** A Japanese Shinkansen bullet train made an emergency stop as a passenger was found at the entrance of a carriage covered in flammable liquid, officials said. The man, said to be in his 30s, and a female passenger, died, according to reports. At least six passengers were injured and several others were reported to be suffering from the effects of smoke inhalation. The woman who died was found at the other end of the carriage on the train, which was bound for the western city of Osaka from Tokyo.

- **8th July 2015: United Airlines experienced Nation-wide Grounding:** United airlines delayed more than 700 flights and cancelled 16, during the 90 minutes of nationwide grounding of all its mainline flights. According to the company they were experienced, a network connectivity issue, due to software malfunction. According to the united president, chairman and CEO Jeff Smisek airline was "working on a root-cause analysis to tell us what it was" that led to the disruption.

- **14th December 2015: A member of Air India's ground crew "sucked" into an Aircraft Engine:** A member of Air India ground crew was "sucked into" an aircraft engine and killed the technician, who worked for Air India died when he was working on the plane that was due to fly from Mumbai to Hyderabad. The plane was "pushing back" from the gate to begin its taxiing to the runway when the accident happened, The Times of India reported. Information collected by Stuart Peake, Master Fellow of the MIRCE Akademy

- **29th January 2016: Two Incidents by South Korean Low-Cost-Carriers:** South Korea's transport ministry is demanding enhanced safety measures such as more flight and ground crew per aircraft and better facilities at airports to service them, after two incidents in the past month. These involved a Jeju Air 737-800 that underwent an emergency descent after the pilot forgot to engage cabin pressurisation, and a Jin Air flight that took off with an unsealed door. Hence, the objective is to convince the 5 LLC, that control more than 50% of domestic flights, that the reputational cost of a crash far outweighs savings from skimping on maintenance or training. Something that other countries have understood. For example Europe, for Ryan Air and Easy Jet have never suffered a major incident or accident-related death, while U.S. operators such as JetBlue, Southwest and Spirit also have safety records comparable to, or better than full-service airlines.

- **19th March 2016: Fly Dubai Flight FZ981 Crash Landing Killing 62 People on the Board:** The final frames of imagery captured by several surveillance cameras of the Boeing 737-800 with 62 passengers and crew plunging into the ground in a steep nose-down attitude at the Rostov-on-Don Airport. It arrived in this area at approximately 2:00 a.m. local time after a 4-hr. flight from Dubai. The first attempt at the instrument landing system approach to Runway 22 ended with a missed approach initiated at more than 1,700 ft. above ground, well above the 480 ft. minimum. It is possible that wind shear conditions, which the approach chart states can be "expected on the final" arrival to the runway, may have played a role in the abort. Climb rates during the first go-around averaged about 2,250 ft. min. up to 8,000 ft., where the aircraft maneuvered in the local area for 25 min. FZ981 later climbed to 15,000 ft., where it held for nearly 1 hr. until attempting a second instrument landing to Runway 22 at approximately 3:30 a.m. On the recording, voices from the cockpit appear to be calm throughout the ensuing approach, informing the tower controller that the aircraft would climb to 8,000 ft. in case of another miss. The pilots reported being "established on the localizer," meaning the aircraft had locked in its lateral guidance on the ILS. As it descended through approximately 1,500 ft. however, the pilot radioed the tower, "Going around, 981."

- **7th April 2016: Unseen Blast Injuries to the Brain Trauma:** Medical profession has long term concern for the supersonic shockwave that accompanies bomb blasts, as it can affect the brain in ways that might not be readily apparent and cause undetected damage. The U.S. Office of Naval Research, ONR, wants to expand understanding of how shockwaves' impact affect the brain, by funding research at two USA Universities that analyse the effect of micro cavitations. They are energy-packed bubbles less than 1 mm in diameter which caused by shockwaves that form and collapse in the brain. They appear, burst and disappear quickly and cannot be detected by brain-imaging technology. Collapsed micro cavitations they can damage surrounding cells and tissue, which creates leakage through the blood-brain barrier, a tight network of blood vessels that allow healthy molecules to enter the brain from the bloodstream while preventing the entry of harmful ones. The research is focused on learning how to recognise damage in the blood-brain barrier, knowledge of which could be used to develop medical treatments for memory loss, headaches and the post-traumatic stress disorder that may result from this injury. One objective is to identify localised biomarkers such as proteins, chemical compounds and blood particles that indicate the presence of micro cavitations. This would help doctors identify areas of the brain that might be injured.

- **17th April 2016: Smoke and fumes event involving Boeing 787, N36962:** Boeing 787-9, (N36962), operated by United Airlines as flight UAL870, departed Sydney, for San Francisco, USA, when cabin crew switched on the aft galley ovens in preparation for meal services. After the two ovens were switched on, there was a short burst of smoke, which set off a fire alarm in a nearby toilet for about one minute. One of the ovens displayed a "FAILURE" message. Several cabin crew detected a strong chemical odour and an electrical smell, as well as a blue haze. The crew immediately pulled all relevant circuit breakers, and switched off all electrical sources to the aft galley. By the time that the in-flight service manager (ISM), together with a relief pilot from the cockpit arrived at the aft galley with fire extinguishers, the smoke had dissipated, but the odour persisted. As it could not be confidently ascertained that the ovens were the sole source of the problem, the captain contacted the ground-based technical operations maintenance controller (TOMC) by satellite phone. It was agreed that the safest option was to return the aircraft to Sydney. As the aircraft was well in excess of its allowed landing weight, fuel was dumped during the descent. The aircraft landed without incident in Sydney with emergency services in attendance. A post-engineering inspection quarantined the suspect oven, and after an inspection, a fuse was replaced. After appropriate testing, the aircraft was released back to service. Boeing and the oven manufacturer investigated the cause of the 'Critical Error' fault displayed on the oven screen. The manufacturer individually tested all oven components. They reported that all individual components worked correctly, however, an additional measurement of the oven motor current detected that the motor did not run smoothly, and tits temperature was also above normal, most likely from insufficient airflow. This known fault had been rectified with a new oven software release. Boeing reported that the oven manufacturer is working with United Airlines to update the software in all relevant ovens in their fleet. The exact cause of the odour could not be determined. . (Source: AO-2016-033)

- **15th May 2016: Smoke event involving Airbus A380:** Qantas Airways Airbus A380 (VH-OQD) was on route from Sydney, New South Wales to Dallas-Fort Worth, USA, when about two hours prior to the aircraft's arrival, a passenger alerted the cabin crew to the presence of smoke in the cabin. The cabin crew then initiated the basic fire drill procedure. Two of the cabin crew proceeded to the source of the smoke with fire extinguishers. At the same time, the customer services manager (CSM) made an all stations emergency call on the aircraft interphone to alert flight crew and other cabin crew to the presence of smoke. The cabin crew located the source of the smoke at seat 19F, on the upper deck. The crew removed the seat cushions and covers from the seat while the CSM turned off the power to the centre column of the seats. When the seat was further dismantled, the crew found a crushed personal electronic device (PED), contained a lithium battery, wedged tightly in the seat mechanism. By that time, the PED was no longer emitting smoke, however, a strong acrid smell remained in the cabin. The crew then manoeuvred the seat and freed the PED and it placed it in a jug of water, which was then put in a metal box and monitored for the remainder of the flight. No passengers were injured and the aircraft was not damaged in the incident. (source AO-2016-053)

- **3rd August 2016: Emirates B777 at Dubai landed with Gear Retracted**: An Emirates Airlines Boeing 777-300, registration A6-EMW performing flight EK-521 from India, with 282 passengers and 18 crew, was on final approach to Dubai's runway 12L at 12:41L (08:41Z) but attempted to go around after first ground contact. The aircraft however did not climb, but after retracting the gear touched down on the runway and burst into flames. All occupants evacuated via slides, 13 passengers received minor injuries, 10 were taken to hospitals, 3 treated at the airport. The aircraft burned down completely. A firefighter attending to the aircraft lost his life. Tthe airline reported that both captain and first officer had accumulated more than 7000 flying hours. The aircraft involved in the "operational incident" was equipped with Trent 800 engines and had been delivered to the airline in March 2003. A ground observer reported EK-521 made a normal approach with the landing gear extended, touched down hard and went around, the gear was retracted, however the aircraft appeared to lack power and sank back onto the runway skidded shaking violently and immediately filling with smoke and came to a stop. All doors were opened, it appeared however not all of them were used for evacuation. After sliding down the chute the passenger began to run, about 100 meters from the aircraft an explosion was heard, as the aircraft erupting into flames", the right wing caught fire and including right hand engine separated from the aircraft.

- **8th August 2016: Passengers Stranded after Delta Flights Grounded Worldwide:** Tens of thousands of people were stranded after Delta Air Lines flights were grounded around the globe due to a system outage. As for the cause of the snafu, Delta pointed to an overnight power outage in its hometown of Atlanta that it said "impacted Delta computer systems and operations worldwide, resulting in flight delays." Delta said that systems were back online by 8:40 a.m. ET, but warned disruptions would continue amid a "limited" resumption of departures. By 1:30 p.m. ET, the airline had canceled 451 out of its daily 6,000 flights. It remained to be seen how large a portion of the carrier's daily schedule would ultimately be cancelled by the end of the day.

- **15th August 2016: RAF Pilot Who Sent A330 Into Plunge With Camera To Be Court-Martialed:** In February 2014, according to the U.K. Military Aviation Authority (MAA) the aircraft’s commander—had placed his personal digital SLR camera between the captain’s seat armrest and the left-hand side-stick controller during a flight from the U.K. to Afghanistan. As the captain moved his seat forward, the position of the camera forced the side-stick fully forward. This initiated a pitch-down command, sending the aircraft into a steep dive, with the A330 losing 4,400 ft. in 27 sec. During the dive, passengers and crew in the main cabin were thrown to the ceiling, with 24 passengers suffering injuries, along with all seven of the cabin crew. Most of the injuries occurred as the individuals came into contact with the ceiling and overhead fittings or were struck by loose objects. Several of the 198 passengers onboard the aircraft are now suing the Ministry of Defence. The eight men and two women have said they have suffered flashbacks as a result of the incident, as well as nightmares and mood swings. Three service personnel have been medically discharged from the armed forces as a result. A crash was only narrowly avoided thanks to the aircraft's flight envelope protection system, the report said. The aircraft made an emergency landing at Incirlik Air Base, Turkey.

- **27th August 2016: Power plant's inlet cowl detached in midair of Boeing 737-700:** A highly unusual negative functionability event took place on the left CFM56-7B engine on a Southwest Airlines Boeing 737-700, when power plant's inlet cowl, on engine number 1, detached in midair, causing the engine to be shut down as well as significantly damaging the airframe. The flight was enroute from New Orleans to Orlando, Florida and landed to Pensacola, Florida, while—appear to show the fan and centrally located spinner intact after the cowl separated. There is no apparent indication that the cowl loss was associated with either a fan-blade failure or the release of a blade. Passengers reported a loud noise accompanied the event, which occurred around 13 min. after takeoff at around 31,000 ft. over the Gulf of Mexico. The cowl is normally attached to the fan case by bolts and two alignment pints located at the 3 and 9 o'clock positions around the inlet. Damage visible to the airframe includes significant buckling of the leading-edge wing root fairing, indicative of a heavy impact from part of the inlet assembly, as well as a puncture of the fuselage skin below the window belt above the leading edge. This latter damage is likely the main cause of the cabin depressurization which occurred on separation of the inlet. Photographs also show dents to the midspan of the horizontal-stabilizer leading edge and, perhaps surprisingly, the leading edge of the left winglet.

- **4th October 2016: Human Error Behind Air Asia X Diversion:** While programming an AirAsia X Airbus A330-300's initial coordinates, a captain's data-entry error, led to myriad navigation errors and an eventual diversion. The March 10, 2015, incident began when the captain entered incorrect coordinates into the Air Data and Inertial Reference System (ADIRS). The longitude was incorrectly entered as 01519.8 east (15 deg. 19.8 min. E. Long.) instead of 15109.8 east (151 deg. 9.8 min. E. Long.). As a result, the aircraft's systems placed it near Cape Town, South Africa, instead of at Sydney Airport's International Terminal Gate 54. The magnitude of this error adversely affected the aircraft's navigation functions, global positioning system (GPS) receivers and some electronic centralised aircraft monitoring alerts, The flight crew did not realise it had a problem until a series of warnings upon takeoff en route to Kuala Lumpur. The crew then attempted to follow the course assigned by air traffic control, including a right turn. But the aircraft, operating on autopilot and guided by the erroneous starting coordinates, turned left instead, crossing the departure

> path of a parallel runway. After nearly an hour of fruitless troubleshooting, the crew diverted to Melbourne Airport; weather at Sydney had deteriorated, and the AirAsia X crew, suspecting navigation problems, wanted a visual approach. The incident's cause was clear: The mistyped longitude triggered a series of events that led the flight crew to believe the aircraft had malfunctioning avionics. But extensive post incident troubleshooting concluded that the only problems were human factor-related: erroneous data entry and missed clues that would have highlighted the problem.

7. Summary

Mirce-mechanics is a new discipline that studies the in-service life of maintainable systems through the sequence of functionability events taking place along the time axis.

Fully aware that the future in-service life of maintainable systems cannot be improved by doing better statistics on the recorded data related to the past in-service life, the author set to collect the physical evidence about the mechanisms that drive system in-service process and originate functionability events.

Having collected the "physical evidence" about the events in the system in-service process the author set up a very detailed research programme with the objective of understanding the mechanisms and processes

In order to understand in-service processes it is necessary to understand their physical causes, and that represented a real challenge. In sense, what is the real cause of say, fatigue, the wind direction change, suncups formation on the blue ice runway, faulty weld, bird strike, perished rubber, maintenance induced error, carburettor icing, to name just a few.

After a numerous studies, discussions and trials, it has been concluded that any serious studies in this direction have to start at the "bottom end" of the physical world, namely with the atom system and to finish at the "top end" of the physical world, the solar system. This range is the minimum sufficient "physical scale" which enables the understanding of system in-service cause-effect relationships and provides enough information for the accurate predictions to be made. In other words, this is the physical range within which, the system functionability events mentioned above (fatigue, the wind direction change, suncups formation on the blue ice runway, bird strike, perished rubber, carburettor icing) take place and could be understood.

The rules, algorithms and methods developed by the Mirce-mechanics should enable the accurate predictions related to the in-service life of maintainable systems to be made. However, analysis and research performed in any "smaller scale" could lead to prediction errors

Further more, by applying the knowledge of Mirce-mechanics during the System Engineering Process it becomes possible to assess the in-service life of design of each design alternative, at the time when a constructive course of action could be taken. This could provide a considerable reduction in testing time, data collecting activities and modifications, which in turn could provide a considerable reduction in development cost and in-service risk.

***8.* Reference:**

[1] Knezevic, J., *Mirce-mechanics*, Founders Lecture, Mirce Akademy, November 1999Woodbury Park, Exeter, UK.
[2] Knezevic, J., System In-service Success – Luck or Knowledge, Proceedings 7. Medjunarodna Konferencija, Upravljanje Kvalitetom i Pouzdanoscu, DQM, Belgrade, Serbia, 16-17 June 2004.
[3] Dubi, A., System Engineering Science, pp168, Mirce Science, Exeter, Great Britain, 2003,
ISBN 1-904848-00-1.
[4] Ponomarev, L.I., The Quantum Dice, pp 251, Institute of Physics Publishing, 1993, Bristol, UK, ISBN 0-7503-0241-0
[5] Petrosky, H., To engineer is Human, The role of Failure in Successful Design, pp 252, Vintage Books, 1992, New York, USA, ISBN 0-679-73416-3
[6] Encyclopaedia Britannica, Millennium Second Edition, CD-ROM

The Job of RMS Community is Provisioning of Work by Maintainable Systems[8]

Dr Jezdimir Knezevic
MIRCE Akademy, Exeter, UK

"*Airlines are in the transportation business; Boeing, Douglas, Lockheed, Airbus, they're in the airplane business. 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 B3 in Chicago at 9.15 to originate the trip to Cleveland, forget it.*"

Jack Hessburg (1934-2013) Grand Fellow of the MIRCE Akademy,

1. Introduction

Since it's beginnings in late 1950s, the Reliability, Maintainability and Supportability, RMS, theories have been based on mathematical theorems rather then on scientific principles. Hence, a massive attempts where made to the further applications of the existing mathematical and operational research methods and analysis without understanding "the functionability mechanics[9]". Then, in mid 1980s, practicing RMS engineers and analysts, who did not have neither ability nor need to understand the mathematics, turned to what they have had, enormous practical experience and analysis like FMECA, MTA, LORA, LSA, LCC and many others were created and applied to the design of maintainable systems. Thus, a large number of the best practices for RMS analysis of the new systems have been developed and used, but still without understanding and addressing "the functionability mechanics". Consequently, during last 60 years the RMS theories made a very little progress, if any, in the direction of becoming the science based foundation for RMS engineering and management profession. The reason is very simple; it has been between the mathematicians who did not have in-service engineering experience and in-service engineers who did not have mathematical skills and yet are put in the design office to perform RMS predictions and influence the design process that is dominated by engineers whose methods and skills are based on the principles of fundamental sciences, like mechanics, thermodynamics, material science, fluid mechanics and so forth.

Even further, majority of the RMS method based on best practises and governing industrial/military standards address specific in-service characteristics of the components of maintainable systems alone, like reliability, maintainability, supportability, testability, availability and similar. However, in the late 1990s the

[8] [8] This paper is dedicated to the life of Sarah Palmer-Tompkins (23.12.1971-8.2.2017) a person whom I never met but whose the most genuine, sincere and cheeky attitudes towards life constantly generated a unique smile in me, during her well covered public appearances.

[9] Functionability mechanics is a part of the Mirce-mechanics that scientifically studies the physical mechanisms and human actions that cause the motion of a maintainable system through functionable and non-functionable states throughout their in-service lives. Dr J. Knezevic

author became fully aware that, despite the fact all of these specialist subjects have their own specifications and contractual requirements, there was nothing to "normalise" them and predict the overall in-service performance of maintainable systems on the "drawing board". Hence, it was impossible to even address the questions how many daily flights "to Cleveland" are likely to be delivered on time during the in-service life of a given aircraft design or how much electrical energy will be delivered by a given design option for a power station or any other measure of functionability performance of maintainable systems.

Hence, it became crystal clear to the author that the purpose of every maintainable system is **not** to deliver MTBF, MTTR, MLDT, MTTS and similar contractually required measures of RMS. Their purpose is to do the **work**[10]. Nothing is intentionally specified, designed, produced and acquired by somebody in order to do nothing. To be in the position to fully address the complex problem of generating accurate predictions of the work done and resources required to support operation and maintenance of maintainable systems, throughout their in-service life, the author resigned from Exeter University, UK, in 1999 and established the MIRCE Akademy at Woodbury Park, Exeter, UK.

2. A Few Words about Mirce-mechanics

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

The development of science started when people began to study phenomena not merely observing them. People developed instruments and learned to trust their readings, rather than to rely on their own perceptions. They recorded the results of their measurements in the form of numbers. Supplied with these numbers they began to seek relationships between them and to write down in the form of formulas. Then the formulas became the only things they came to trust when they began to predict things they could not physically experience.

However, people communicate with each other by means of words, not formulas. Hence, when they want to speak about new phenomena they have to invent concepts that correspond to them. Even though these concepts are often quite extraordinary, people become accustomed to them and learn to apply them correctly and even create images for themselves that they associate with the new concepts.

Years of intensive research at the MIRCE Akademy have generated a new, science-based, body of knowledge, named Mirce-mechanics. It comprises axioms, laws, mathematical equations and calculation methods that enable accurate predictions of the work done by the maintainable system and the work require to be done on the system to maintain the flow of functionality through in-service life [1]. Thus, from now on, design teams will be able to "normalise" all feasible solutions regarding all relevant RMS issues at the system level, in an integrated and mutually related manner, by using Mirce-mechanics obtained predictions of functionability performance to compare all feasible options to select the most suitable compromise

[10] In Mirce-mechanics the work is considered to be done by a maintainable system when, at least one, measurable function is deliver at a unit time. (Dr J. Knezevic)

for all stake holders, based on their through life needs. It is an imperative, as a maintainable system comprises not only the entity delivering functionality performance but also functionability performance, which is govern by every facet of the universe that is needed to operate, maintain and support it. This includes, but is not limited to: the time it is intended to operate; the capacity it has to do work in a given time; the supplies and resources required to sustain and maintain its operation; the capability of the supplies and resources to provide sustainment and maintenance, the environment around it (weather, dust, contaminants), location (global and installed), access (physical and operational), financial constraints and many more. [2]

The main objective of Mirce-mechanics is to provide a platform for design engineers, scientists, operators, maintainers, logisticians, programmers, planners, budget managers, economists to get involved into complexity of the process of quantifying the consequences of their specialist decisions, usually at the components and modules level, on the functionability performance of a given[11] maintainable system in the future.

3. A few words about the laws of probability

The role of probability in Mirce-mechanics is one of prediction. In classical science two identical tests under identical conditions should always yield the same end result. This is idea behind classical causality, or determinism. However, in Mirce-mechanics causality is peculiar in that even under invariable conditions it can only give the probability of the occurrence of functionability event in a single test; on the other hand, it can, with absolute certainty, predict the distribution of occurrence of functionability event for a maintainable system type.

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 a specific functionability event 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 that particular functionability event to each individual system. 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 chances of occurrence of each individual functionability event, which is one of the possible outcomes of the in-service life

[11] In Mirce-mechanics a given maintainable system is define through the following elements: Functionality principles of a system (mechanical, electronic, thermal, electrical, nuclear, etc.), Structure/construction of a system (dependencies and redundancies), Operational concepts and scenarios (continuous, seasonal, one off), Maintenance rules (schedule inspections, replacement, testing and so forth), Logistics support (training, spares, facilities, tools, equipment, etc.) and Environmental conditions (climate and weather)

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

In everyday notion the expression “each event has its own cause” needs no further explanation. Causality in science requires a law to guide us through the sequence of events in time. Mathematically, this law takes the form of a differential equation, known as an equation of motion. In classical mechanics such equations, Newton’s equations of motion, enable us to predict the trajectory of a particle’s motion and many other natural phenomena defined by the laws of science that accurately predict functionality performance of a maintainable systems.

However, in Mirce-mechanics such causality cannot be found. What is found is a statistical causality that can only be predicted through probabilistic distributions. However, probabilistic based laws are even more powerful than those laws that govern mechanical deterministic relationships, since it identifies and singles out patterns in the “chaos of possible random events”. Phrases like “statistical causality” and “probabilistic regularity” could sound very strange to the deterministically minded people, but in Mirce-mechanics it is only possible to utilise them when dealing with functionability phenomena, like wear, thermal deformation, corrosion, no-fault-found, creep, bird strike, battlefield damage, bogus part, transport damage, fatigue, and many other. In fact, there is no logical paradox here as the concepts of “probability” and “regularity” are complementary ones. Hence, the starting axiom of Mirce-mechanics is that probability is a property inherent in the motion of functionability phenomena through the life of maintainable systems, rather than a convenient mathematical trick used to account for observational evidence.

4. Mirce-mechanics Equation for Work of Maintainable Systems

According to the Mirce-mechanics a work is done when a maintainable system considered delivers functionality at a unit of time. To deliver functionality system must be being in functionable state. Thus, the expected work done by maintainable system type during a given interval of calendar time, W(T), measured in Hours, [Hrs], can be calculated by making use of the following equation:

$$W(T) = \int_0^T y(t)dt \qquad [Hrs] \qquad 1$$

where y(t) is the quantity of work done at a unit time that is quantitatively defined by Mirce Functionability Equation [3]

$$y_S(t) = 1 - \varphi_S(t) + \mu_S(t) \qquad 2$$

In the Equation 2 in-services measurable variables $\varphi_S(t)$ and $\mu_S(t)$ represents the expected number of functionability events that cause transitions of a maintainable system to non-functionable state from its birth to the given instant of time t and the expected number of functionability events that return the system in the functionable state in the given interval of time, correspondingly. The later one comprises of the time a system spends in active maintenance and the time the system spends in support (waiting for spares, trained personnel, tools, equipment, facilities and other necessary resources.). Equation 1 drives equations for the predictions of the in-service costs, which are monetary value of the resources used for the execution of operation, maintenance and support tasks.

Mirce-mechanics principles described in the paper are a part of the current design processes at Finmeccanica Airborne & Space Systems Division, Edinburgh, UK [4]

5. Summary

Through Mirce-mechanics the RMS community has got a single mathematical equation for predicting the expected work done of the future maintainable systems that simultaneously embraces all three in-service processes, namely operation, maintenance and support. This enables expertise and responsibilities of all RMS specialists to be integrated during the design process and the expected work done to be predicted for each feasible alternative of maintainable system considered and thus compare them in respect to expected whole life cost. It is necessary to stress that all of this became available at the time when all deign changes could be made at almost no extra time and cost. Thus, designing an aircraft that will be delivering specified number of flights on time or power station with guaranteed annual delivery of energy became reality due to Mirce-mechanics principles and mthods.

6. References

[1] Knezevic, J., Functionability in Motion, Proceedings of 1st DQM International Conference on Life Cycle Engineering and Management, pp.10-25, Belgrade, Serbia, 2010,
[2] Knezevic**, J**., Atoms and Molecules in Mirce Mechanics Approach to Reliability, SRESA Journal of Life Cycle Reliability and Safety Engineering, Vol 1, Issue 1, pp 15-25, Mumbai, India, 2012. ISSN-22500820
[3] Knezevic**,** J., Mirce Functionability Equation, Int. Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 8(Version 7), August 2014, pp.93-100
[4] Mulholland, A., The Shape of things to come: A look at the different ways we approach predicting in-service reliability of new equipment, 2016 Annals of Mirce-mechanics, pp 63-81, MIRCE Akademy, Exeter, UK

Mirce- mechanics Approach to the Analysis of the Cosmic Radiation Impact on Aviation Reliability

Dr J. Knezevic
MIRCE Akademy, Exeter, EX5 1JJ, UK

Abstract

The main objective of this paper is to demonstrate the necessity of addressing all physical causes that lead to the transition of maintainable systems from positive to negative functionability state during their lives. Addressing the reliability characteristics of components and systems in isolation from the analysis of the impact of the natural environment on it, is not sufficient. Hence, results of the research performed in accordance to the Mirce-mechanics principles, have shown the significant impact of cosmic radiation on the in-service behaviour of aviation systems Due to the rapid advances in electronics technology and the unrelenting demand for increased avionics functionality the complexity of avionics systems has risen exponentially. Hence, ever more advanced microprocessor and memory semiconductor devices are being used that exhibit an increased susceptibility to cosmic radiation phenomena. Single Event Effects have been the primary radiation concern for avionics since the late 1980's when the phenomenon, which had previously only been observed in orbiting satellites, also began to appear in aircraft electronic systems. The trend with each new generation of avionics system is to use increasing quantities of semiconductor memories and other complex devices that are susceptible to decreases in reliability due to ionising radiation from the cosmic rays from space. and alpha particles from radioactive impurities in the device itself. The interaction of this radiation can result in either a transient 'soft error' effect such as a bit flip in memory or a voltage transient in logic, alternatively a 'hard error' can be induced resulting in permanent damage such as the burn out of a transistor. Thus, this paper concludes that Mirce-mechanics approach to reliability is the only way forward for all members of the reliability community who wish to develop a method for accurate predictions of reliability, cost and effectiveness of aviation systems at early design stages, rather than to measure their in-service values and produce end of life statistics.

1 Introduction

Earth weather, manifested through physical phenomena like wind, snow and rain, has significant terrestrial impacts on the functionability of maintainable systems. Physical causes of these metrological phenomena are reasonably well understood and included in reliability analysis of maintainable systems.

Space weather, manifested through physical phenomena like evolving ambient plasma, magnetic fields, radiation, particle flows in space, has significant impact on the functionability of maintainable systems [1]. The effects of space weather are observed in the interruption or degradation of functionality and performance of space related systems during their in-service lives. In addition, increased radiation due to pace weather may lead to increased health risks for astronauts participating in manned space missions. The aviation sector may also experience damage to aircraft electronics and slightly increased radiation doses at aircraft altitude during large space weather events. Space weather effects on ground can include damage and disruption to power distribution networks, increased pipeline corrosion and degradation of radio communications. Collateral effects of longer-term outage would likely include, for example, disruption of the transportation, communication, banking, and finance systems, and government services.

The complexity of avionics systems has risen exponentially, due to the rapid advances in electronics technology and the unrelenting demand for increased avionics functionality. Hence, ever more advanced microprocessor and memory semiconductor devices are being used that exhibit an increased susceptibility to cosmic radiation phenomena. Since the late 1980's, the Single Event Effects, SEEs, have been the primary radiation concern for avionics when the phenomenon, which had previously only been observed in orbiting satellites, also began to appear in aircraft electronic systems. According to Baumann, Left unchallenged, soft errors have the potential for inducing the highest failure rate of all other reliability mechanisms combined." [2]

Cosmic radiation causes daily concerns regarding the reliability of avionics equipment, particularly for those systems that are considered safety critical. The trend with each new generation of avionics system is to use increasing quantities of semiconductor memories and other complex devices that are susceptible to failures induced by ionising radiation from the cosmic rays from space and alpha particles from radioactive impurities in the device itself. This radiation can result in either a transient 'soft error' effect such as a bit flip in memory or a voltage transient in logic, alternatively a 'hard error' can be induced resulting in permanent damage such as the burn out of a transistor.

If device memory cells used for flight safety or mission critical functions are affected the concern is that the loss of key system functionality due to corrupted data could cause a flight safety or mission critical failure. The ability to predict and quantify the rate of occurrence of erroneous data bits in memories or voltage transients in logic is one of the key objectives in the field of avionics reliability research. The reliability of their operation is influenced by a multitude of different factors extending from the Earth's atmosphere to the far reaches of space beyond our own galaxy. In order to determine the probabilities of occurrence and the resultant impact of functionability events on a system a full awareness of the dynamic nature of the environmental phenomena is required. To identify the causes of functionability events the mechanisms that cause those physical phenomena must first be understood. [3]

Consequently, the main objective of this paper is to argue that the Mirce-mechanics[12] approach to the analysis of the impact of cosmic radiation on reliability of avionics is the only way forward for all members of the reliability community who wish to make the reliability predictions, which will be confirmed during the operational processes of the future systems. In author's view, accuracy of the reliability predictions required scientific understanding of functionability phenomena [3]. This paper advocates that research of this nature must include the understanding of the cosmic phenomena, in order for occurrence of functionability events to be understood. Then and only then, accurate and meaningful reliability and safety predictions become possible, which will ultimately lead to the reduction of the probability of the occurrence of failure events during the life of maintainable systems.[4]

2. A Few Words on Mirce-mechanics

While, aerodynamics is the scientific foundation of the functionality performance of aircraft, Mirce-mechanics: is a scientific theory of the functionability performance of maintainable systems, including aircraft. Its axioms, mathematical formulas, rules and methods enable accurate predictions of a system's measurable functionability performance characteristics like reliability, punctuality and others to be made with probabilistic regularity. [4]

After several decades of observing and experiencing in-service behaviour of maintainable systems, the author has concluded, that from functionability[13] point of view, at any instant of time a maintainable systems can be in one of the following two states:

- Positive Functionability State, PFS, is the state in which a maintainable system is able to deliver expected functionality and functionability performance
- Negative Functionability State, NFS, is the state in which a maintainable system is not able to deliver expected functionality performance, for whatever reason whatsoever.

The motion of a maintainable system through functionability states, in respect to time, is generated by functionability actions, which are classified as:

- Positive Functionability Actions, PFA, are human activities or natural processes that compel the system to return to PFS.
- Negative Functionability Actions, NFA, are natural processes or human activities that compel the system to move NFS.

The motion of a maintainable system through functionability states is observed through occurrences of functionability events, which are classified as:

[12] Mirce-mechanics is a theory created by subjecting the motion of maintainable systems through Mirce-space to the laws of science & mathematics, to develop a method for accurate predictions of their functionability performance from the early stages of a design process till final disposal.
[13] Functionability, n, ability of being functional, Knezevic, J., Reliability, Maintainability and Supportability – A probabilistic Approach, Text and Software package, pp. 291, McGraw Hill, London 1993. ISBN 0-07-707691-5

- Positive Functionability Events, PFE, well defined occurrences in time when transitions of maintainable systems from NFS to PFS take place.
- Negative Functionability Events, NFE, well defined occurrences in time, when transitions of maintainable systems from PFS to NFS take place.

Consequently, Mirce-mechanics as the science of the motion of maintainable system type through functionability states resulting from any functionability actions whatsoever and the actions required to produce any functionability related motions. Thus, a life of maintainable system type could be considered as a sequence of functionability events through time that is quantified by functionability performance.

The main objective of Mirce Mechanics is the scientific understanding of mechanisms that generate positive and negative functionability events.

For years, research studies, international conferences, summer schools and other events have been organised in order to explain and draw attentions to just the physical scale at which failure phenomena should be studied and understood. In order to understand the motion of functionability events it is necessary to understand the physical mechanisms that cause their occurrences. That represented a real challenge, as the answers to the question “what are the discrete physical and chemical processes that lead to the occurrence of given functionability events” have to be determined. Without accurate answers to those questions the prediction of their future occurrences is not possible, and without ability to predict the future, the use of the word science becomes inappropriate.

After a numerous discussions, studies and trials, it has been concluded that any serious studies in this direction, from Mirce-mechanics point of view, have to be based between the following two boundaries [5]:

- the “bottom end” of the physical world, which is at the level of the atoms and molecules that exists in the region of 10^{-10} of a metre,
- the “top end” of the physical world, which is at the level of the solar system that stretches in the physical scale around 10^{+10} of a metre.

This range is the minimum sufficient “physical scale” which enables scientific understanding of relationships between physical phenomena that take place in natural environment and the physical mechanisms that generate the failures of maintainable systems.

Cosmic radiation if one of the interacting factors from the physical world that directly impacts the functionability performance of maintainable systems in general and aviation in particular. This paper therefore considers major properties of cosmic phenomena, generated in the physical world, that impact the functionability performance of aviation systems. To achieve this goal, this paper examines the cosmic phenomena to understand their mechanisms of occurrence; describes the potential physical processes that regenerate negative functionability events and their possible impacts on aviation systems reliability and safety.

3. Naturally-occurring Radiation

Naturally generated radiations permeate everything on the planet Earth at all times of the day. Some of them are generated near us, on a radius of a few thousand light-years, while some only reach our planet after a ten- to 11-billion-year journey. They are unnoticeable to humans, but some researchers believe they may have played a crucial role in the development of life on Earth, and maybe even in some extinction events.

Cosmic radiation is made up of high-energy protons, which are mostly generated by supernova explosions and the ensuing shock waves. There is, at this point, no clear way of finding out where they came from, mostly because they are prone to the influence of magnetic fields. This means that they “bounce” inside the galaxy for up to a few million years, before finally making their way to Earth. Still, once here, they usually don't reach the surface. They collide with ions (electrically charged atoms) in the upper atmosphere, and break up into a shower of “secondary” particles, which are harmless.

In the natural environment the fundamental radiation particles that can cause transient errors in electronic devices, can be classified into the following three groups:

- High-energy cosmic ray neutrons.
- Thermal or low energy cosmic ray neutrons.
- Low energy alpha particles emitted from within the semiconductor device and packaging materials.

Each of these particle categories is different in terms of their physical characteristics like, flux, energy level, charge or composition. However, in essence a single particle of any of the above forms could generate a soft error if it deposits sufficient charge within the susceptible volume of a device.

The cosmic ray particles penetrate the Earth's atmosphere and collide with atoms of air. These molecular collisions give rise to the production of more particles such as protons and neutrons and others. A cascade of particles is generated by successive interactions as they penetrate deeper and deeper into the atmosphere. As a result, the flux of particles increases and reaches a maximum of about 20 kilometres above sea level. Below this point the intensity starts to decrease due to energy losses and particle interactions.

3.1 Galactic Cosmic Rays

Galactic Cosmic Rays are charged particles that originate outside our solar system. They consist mainly of fully stripped atomic nuclei along with some electrons, positrons and anti protons. The nuclei are composed mainly of protons and helium nuclei, while about 1% are heavier nuclei representing all know elements in the periodic table. They travel through the Galaxy with a wide range of velocities up to near the speed of light. Recent experiments have indicated that the low to moderate energy cosmic rays are almost certainly of Galactic origin. The currently favoured theory for the origin of Galactic cosmic rays is that they are produced by a special form of acceleration (Fermi acceleration) at strong shocks that occur at the boundary of supernova remnants.

Because the particles are charged they interact with the irregular magnetic fields in interstellar space so that by the time they arrive at Earth, all information on the direction of their sources is lost.

Consequently the distribution of cosmic rays in interstellar space and near the Earth is similar in all directions (isotropic). The intensity of galactic cosmic radiation has not varied significantly over the last few million years.

3.2 Solar Energetic Particles

Our Sun constantly emits a stream of particles known as the **solar wind** that varies in speed and intensity from day to day. The solar wind is caused by the expansion of the solar corona. Because the energy of the particles in the solar wind is relatively small, they are easily deflected by the Earth's magnetic field and they do not impinge on the Earth's atmosphere. However, on occasions, the surface of the Sun releases sudden outbursts of energy in the form of gamma rays, x-rays and radio waves.

This activity is governed by an eleven-year cycle during which it rises to a maximum and then becomes relatively quiet again. The frequency and strength of these so-called flare events is generally highest around the solar maximum period. During these events electrical activity is great and moving magnetic fields are present which accelerate matter in the solar corona and produce high-energy charged particles. The Earth is connected magnetically to the Sun by field lines and if the solar particle event occurs at a connection point, then the energetic particle accelerated from the corona will be observed at Earth. Their overall rate of occurrence is one approximately every month, so they are rather rare. The phenomena can last for periods of from hours to several days and their energy distribution varies during their lifetime and from event to event. The intensity of the protons can rise by anything up to several million times normal values and very high energies can be observed in the more dramatic cases. In some cases the energies are sufficient to allow the particles to penetrate deeply into the Earth's atmosphere and increase the radiation field at aircraft altitudes.

Only a small fraction of the solar particle events, on average one per year, causes an increased dose rate at aviation altitudes. Those events can be observed with neutron monitors at ground level and are called ground level events (GLEs). The largest events often take place on either side of the period of maximum solar activity as measured by sunspot number. Any rise in dose rate associated with an event is quite rapid, usually taking place in minutes. The duration may be hours to several days. The prediction of which events will give rise to significant increases in dose rate at aircraft altitudes is not currently possible. Estimation of the doses to aircraft crew in the event of a GLE must be made retrospectively. This is possible due to the existence of a number of geomagnetically dispersed ground level neutron monitors, and because the observed neutron fluency at ground level is primarily caused by the cosmic radiation.

Sometimes decreases in the dose rate also occur as an effect of increased solar wind and the increases in associated magnetic field. Such events are called “Forbush” decreases. They may occur on a handful of occasions each year and may last for several days. Decreases of more than 20 % have been reported.

4. The Earth's Magnetic Field

The Earth's magnetic field plays an important role in shielding us from the lower energy component of the cosmic radiation. The interaction between a moving charged particle and a magnetic field causes the particle to be deflected.

Generally speaking, particles approaching the Earth with very high speeds are only slightly deflected by the Earth's field and they can penetrate into the atmosphere. The probability to do so depends on the location at the top of the atmosphere and particle speed. However, lower speed particles, which approach the Earth from space, are deflected significantly and can be forced into trajectories that take them back into space. Thus a large part of the hazardous radiation to which humans could be exposed is deflected away form the Earth.

5. Single Event Effects in Avionics

In electronic devices, Single Event Effects, SEE, are induced by charged particles, with high energy, which reach the Earth’s atmosphere from all directions. These charged particles, with high energy, are called cosmic rays. Single Event Effects occur when a single particle (neutron, proton or other heavy ion) interacts with the atoms that makeup a semiconductor contained within the electronic component of an aircraft system. Some examples of Single Event Effect types are:

- Single Event Upsets, SEU,
- Single Event Latchup , SEL,
- Single Event Gate Rupture, SEGR,
- Single Event Burnout, SEB.

The susceptibility of the electronics, used in aircraft, has increased due to the decreasing size of integrated circuit components. A larger number of Single Event Effects are more likely to occur on aircraft flying at higher altitudes and/or high polar latitudes.

Potential Effects on The effects of Single Event Effects on aircraft systems can be varied. The effect could: result in a hardware failure, be transitory in nature and go un-noticed. When the effect causes the malfunctioning of a system and the crew reports the system malfunction, the subsequent re-test on the ground or in the air may not reproduce the system malfunction. This can result in a ‘no fault found’ entry in the aircraft technical log and the system/equipment may continue to operate correctly with no further system malfunctions.

Aircraft systems and functions, which may be affected, include:

- fly-by-wire technology,
- autopilot,
- flight warning,
- communication (voice and data),

- navigation
- displays
- FADEC (Full Authority Digital Engine Control)
- Any other aircraft system containing electronic components.

It is necessary to stress that each communication and navigation system could be affected to varying degrees. It is not expected that the current levels of Single Event Effects would affect all communication and navigations systems simultaneously.

6. Physical Analysis of SEE on Avionics

Single Event Effects have been the primary radiation concern for avionics since the late 1980's when the phenomenon, which had previously only been observed in orbiting satellites, also began to appear in aircraft electronic systems.

The principal SEE affecting avionic devices is the Single Event Upset caused when a sole incident particle creates a charge disturbance of sufficient magnitude in a memory cell, flip-flop, latch or register to reverse or flip its currently stored data state. Alternatively, in logic or support circuitry a transient voltage pulse can be generated that dependent on the right conditions can propagate through the logic of the device and become latched into a memory cell. Voltage spikes on power supply lines and noise can also cause transient errors, however appropriate shielding and filtering design measures can suppress these types of disturbances.

The primary sources of radiation are high-energy cosmic particles, low energy (thermal) neutrons and low energy alpha particles emitted from device and packaging contaminants.

Radiation can affect electronic devices as the consequence of a single energetic particle strike, termed 'single event' or as multiple strikes over an extended period of time. The effects due to multiple events, Total Ionisation Dose, TID, and displacement damage manifest gradually in electronic components as damage is accumulated over time. These total dose effects and hard SEEs whilst relevant to electronic systems operating in the harsher space environment have a negligible effect on current semiconductor devices used in the terrestrial environment.

Whilst each form of SEE is considered in this paper the main focus will be on SEUs which are the dominant mechanism affecting electronic devices in the avionics environment.

The second most prevalent SEE is the Multiple Bit Upset, MBU, which occurs when a single particle causes the upset of two or more memory cells. However, it only form a fraction of the total number of SEUs, which means that they have little significance except for memory architectures applying Error Detection and Correction techniques. In these circumstances, dependent on the type of error correction technique employed, multiple bit errors could have significant consequences if the protected memory is used for flight or mission critical applications. MBUs are generally assumed to attribute 3% of the total upset rate, although rates as high as 5% have been reported. [8]

Following MBU, Single Event Functional Interrupt, SEFI, and Single Event Latch ups, SEL, account for the majority of the remaining proportion of SEEs affecting avionic devices. SEFI occurs when an upset initiates an IC test mode or reset mode that causes the device to temporary loses functionality. SEL arises when an incident particle creates a charge disruption sufficient enough to effectively short circuit the device resulting in its permanent change of state or in some circumstances permanent damage if excessive current flows as a result of the latch-up.

The Single Event Transient, SET, is the last of the single effect events of avionics relevance that can generate soft errors in the core logic of microprocessors and microcontrollers. [8] They are transient and non-destructive in nature, which are capable of producing a soft error, manifested as the storage of an erroneous data value in registers, memories or latches (only if it is propagated through the logic pathways of the device). This is dependent on the dynamic state of the logic at the time of the particle induced nodal voltage transition and the configuration of the logic pathways within the device. If a soft error occurs, normal system behaviour can be restored by resetting or rewriting the incorrect data.

Of all the forms of SEE, SEUs are the most prevalent in avionic electronic devices covering 90% of events, followed by MBUs (5%), Single Event Functional Interrupt (3%) and finally Single Event Latchup (2%).

The first efforts to calculate SEU rates were presented in two papers in 1984, Tsao et al. [10] and a companion paper by Silberberg et al. [11]. The former paper detailed methods of calculating SEU rates from primary & secondary cosmic rays reaching down to 40,000ft and the latter paper introduced methods for calculating SEU rates resulting from secondary neutrons in the atmosphere.

The reason that semiconductors have become susceptible to SEEs in the terrestrial environment rather than existing solely in space can be partially attributed to the commercial demands for increased functionality and performance, whilst lowering power consumption and cost. To fulfil these requirements component manufactures have continued to reduce the geometry size of integrated circuits with each new generation resulting in higher gate speeds, increased feature density and reduced power consumption.

Whilst technology scaling enables the demands of system designers to be met the downside of this is an increased sensitivity to radiation. Within a memory device this is caused by a reduction in the capacitance inside a cell and a significant increase in the number of cells that could potentially be upset within each device. Less capacitance in a device due to the shrinking of process technology and reduced supply voltage means that the minimum amount of charge necessary to hold data in a device, either logic 1 or 0 is also reduced. This quantity of charge, known as the critical charge, is therefore more susceptible to a charge disturbance caused by an incident radiation particle, thus eroding the components resistance to SEUs. A lower nodal critical charge is therefore more likely to be ‘upset’ by incident particles with a lower energy, because the flux of energetic particles increases at lower energy levels.

The components most susceptible to SEU are therefore devices that contain the largest number and density of potentially volatile bits namely memories and microprocessors. Table below contains a list of the devices that are currently considered to be the most susceptible to SEU in aircraft avionics systems and includes the specific regions within the architecture that are most at risk.

Devise Type	Sensitive Areas
SRAMS and DRAMS	Memory cells and control logic.
Microprocessors and Microcontrollers	Registers, cache, sequential and combinational control logic.
FPGAs and ASICs	Combinatorial logic and sequential logic

Opto-electronics and power switching components are also susceptible, to various forms of hard and soft SEE but are not considered in this paper due to their very low probability of failure in the avionics radiation environment.

Each of the factors discussed in this section, increased functionality and performance, lack of specialist devices, lower critical charge and higher cell density all impact upon the SEU tolerance of advancing semiconductor designs.

The net effect is an increase in the overall device SER that if not adequately mitigated against using appropriate methods such as error detection and correction (EDAC) and architectural redundancy, will result in an increased system SER, plus potentially an increase in the number of mission or flight safety critical negative functionability events.

7. Evaluation of the Cosmic Radiation Exposure of Aircraft Crews

Although Hess's discovery of cosmic radiation was made only a few years after the Wright brothers' first flight it is unlikely that even they could have realised that within a few decades, millions of air passengers and crew would be travelling through this complicated radiation field each year. Naturally, like the avionics is affected by cosmic radiation, the travelling public is affected too. [12] However, the most affected humans by the impact of cosmic radiation are Aircraft Crews, who are exposed to them for thousands of hours during their professional lives. [13]

Although the analysis of the impact of cosmic radiation on aircraft crews and travelling public is beyond the scope of this paper it is worth pointed out that the annual dose to air crew rarely exceed 6 mSv[14], which is well below the average annual dose limit to radiological workers, which is 20 mSv. However, it is necessary to point out that the dose to the unborn child is 1 mSv once the pregnancy has been, discovered [14]

8. Conclusion

The main objective of this paper was to advocate the necessity of addressing all physical causes that lead to the transition of maintainable systems from positive to negative functionability state during its in-service life. Addressing the reliability

[14] The millisievert (mSv) is a scientific measure of the absorption of radiation by the human body.

characteristics of maintainable systems in general and avionics in particular, in isolation from the investigation of the impact of the natural environment is not sufficient. Hence, Mirce-mechanics approach to the reliability analysis of avionics, presented here; have shown the significant impact of cosmic radiation on the occurrence of negative functionability events, and consequently, the necessity for addressing them when the reliability characteristics of avionics are considered and predicted, at the design stages of their life cycle management process. [4]

Single Event Effects (SEEs) have been the primary radiation concern for avionics since the late 1980's when the phenomenon, which had previously only been observed in orbiting satellites, also began to appear in aircraft electronic systems. Cosmic radiation causes daily concerns regarding the reliability of avionics equipment, particularly for those systems that are considered safety critical. The trend with each new generation of avionics system is to use increasing quantities of semiconductor memories and other complex devices that are susceptible to failures induced by ionising radiation from the following two main sources: cosmic rays from space and alpha particles from radioactive impurities in the device itself. The interaction of this radiation can result in either a transient 'soft error' effect such as a bit flip in memory or a voltage transient in logic, alternatively a 'hard error' can be induced resulting in permanent damage such as the burn out of a transistor. These functionability effects caused by a single radiation event are collectively termed as Single Event Effects.

The research results obtained by applying the principles of Mirce-mechanics principles to the scientific understanding of the physical mechanisms that lead to the occurrence of the Single Event Upset, which is the principal SEE affecting avionic devices, are presented in this paper. It is caused when a sole incident particle creates a charge disturbance of sufficient magnitude in a memory cell, flip-flop, latch or register to reverse or flip its currently stored data state. Alternatively, in logic or support circuitry a transient voltage pulse can be generated that dependent on the right conditions can propagate through the logic of the device and become latched into a memory cell.

Consequently, this paper concluded that the scientific approach to reliability is the only way forward for all members of the reliability community who wish to make accurate predictions that will be confirmed during the operational processes of the future systems. For that to happen scientific understanding of functionability phenomena is required. Further more, this paper advocates that physical scale from 10^{-10} metre to 10^{+10} metre must be considered in order for functionability mechanisms like, single event upset, and many others, to be understood. Only then, accurate and meaningful reliability predictions become possible, which is imperative for the development of the risk-based technology and their successful applications.

9. Acknowledgement

I wish to express my gratitude to the professionalism of Ian Zaczyk, Doctoral Diploma student of the MIRCE Akademy, whose relentless research on this subject has produced a significant body of knowledge that is used as the foundation for many research projects related to cosmic radiation, at the Akademy.

10. Referemces

[1] Knezevic, J., Papic, Lj., Space Weather as a Mechanism of the Motion of Functionability through Life of Industrial Systems, Journal, "Advances in Industrial Engineering and Management", Vol. 4, No. 1 (2015), 1-8, American Scientific Publishers, Printed in the United States of America. Print ISSN: 2222-7059; Online ISSN: 2222-7067).

[2] Baumann, R., "Radiation-induced soft errors in advanced semiconductor technologies, " IEEE Transactions on Device and Materials Reliability, vol 5, No 3, pp. 305–316, Sept. 2005.

[3 Knezevic, J. Time To Choose between Scientific and Administrative Approach to Reliability, Journal of Applied Engineering Science, No 3,. Year 2012, Vol 10, Belgrade, Serbia.

[4] http://www.mirceakademy.com/uploads/Mirce-Mechanics-Web-2017-1-11.pdf

[5] Knezevic, J/, Atoms and Molecules in Mirce-mechanics Approach to Reliability, SRESA, Journal of Life Cycle Reliability and Safety Engineering, Vol 1, Issue 1, pp 15-25, Mumbai, India, 2012. ISSN-22500820

[6] Wernik, A., What is Space Weather?, Space Research Centre, Polish Academy of Sciences, pp 27-32, Warszawa, Poland ttp://www.cas.uio.no/Publications/.pdf

[7] Zaczyk. I., Knezevic, J., Cosmic Phenomena in Mirce Mechanics Approach to Reliability and Safety, SRESA's International Journal of Life Cycle Reliability and Safety Engineering, pp 41-50, Vol 2. Issue 2, April 2013, Mumbai, India, ISSN-22500820

[8] Knezevic, J., Functionability in Motion, Proceedings 10th International Conference on Dependability and Quality, DQM Institute, 2010, Belgrade, Serbia.

[9] Zaczyk. I, "Analysis of the Influence of Atmospheric Radiation Induced Single Event Effects on Avionics Failures", Master Dissertation, MIRCE Akademy, Exeter, UK, 2010.

[10] C. H. Tsao, R. Silberberg, and J. R. Letaw, "Cosmic ray heavy ions at and above 40,000 feet, "IEEE Trans. Nucl. Sci., vol. 31, pp. 1066–1068, Dec 1984.

[11] R. Silberberg, C. H. Tsao, and J. R Letaw, "Neutron generated single event upsets," IEEE Trans. Nucl. Sci., vol. 31, pp. 1183–1185, Dec 1984.

[12] Bartlett, D.T. *Radiation Protection Concepts and Quantities for the Occupational Exposure to Cosmic radiation.* Radiat. Prot. Dosim. **86** 263-268 (1999).

[13] Bartlett, D.T., Tommasino, L., Beck, P., Wissmann, F., O'Sullivan D., Bottollier-Depois, J.-F. and Lindborg L. *Investigation of Radiation Doses at Aircraft*

Altitudes during a Complete Solar Cycle: DOSMAX- A collaborative Research Programme. Presented at the 12th Biennial Topical Meeting at XXX 2002.

[14] Beck, P., Ambrosi, P., Schrewe, U., O'Brien, K., *ACREM, Aircrew Radiation Exposure Monitoring.* Final Report of European Commission contract no. F14P-CT960047 OEFZS, Report G-0008, November (1999). European Commission draft version of *Cosmic Radiation Exposure of Aircraft Crew.*

1.

New Book: MIRCE Science by Jezdimir Knezevic

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, the theory for predicting functionability performance of functionable system types. This long and demanding journey consisted of three 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 phenomena of operation, maintenance and support processes (Part 1 of the book).
- The second took the author to universities, libraries, institutes, companies and other organisations worldwide, in the quest for the scientific understanding of the mechanisms that lead to the occurrence of functionability events, resulting from physical, environmental and human actions. (Part 2 of the book).
- The third culminated in the creation of MIRCE: Functionability, Operability, Maintainability, Supportability and Profitability Equations, the mathematical derivation of which has been fully described in this book, based on MIRCE: Functionability Field and Space. (Part 3 of the book).

MIRCE Science comprises axioms, laws, mathematical equations and calculation methods that enable quantitative predictions of the impact of the physical world and in-service rules on the functionability performance of each feasible option of the future functionable system type to be made. The complexity of this undertaking, according to Jack Hessburg (1934-2013), the World's first Chief Mechanic (Boeing 777), requires the intellectual effort equal to winning a Nobel Prize!

Format: A4, Size: 232 pages
Media: Hard copy, hardback
Inside the book http://www.mirceakademy.com/uploads/Book-sample.pdf
Price; £50.00
Postage; £3.00 (UK), £9.00(Europe), £15.00 (Others)
Order Form:
http://www.mirceakademy.com/uploads/ORDER%20FORM%20MIRCE%20Science.pdf

Call for Papers.. Call for Papers.. Call for..

2018 Annals of MIRCE Science

Published by the MIRCE Akademy to facilitate exchanges of knowledge and experience between: scientific, engineering and management professionals, which are interested in MIRCE Science.

The Annals welcomes the following types of original contributions:

- Presentations of the research results related to all aspects of MIRCE Science
- Applications of existing MIRCE Science knowledge
- Observational knowledge that could be beneficial for further developments of MIRCE Science
- Reports, book reviews and short news that are of a general benefit to MIRCE Science

Potential authors please see: Guidance for Authors at http://www.mirceakademy.com

Papers..Call for Papers..Call for Papers...

Please send your paper to Dr Jezdimir Knezevic, by:

- **Email:** jk@mirecakademy.com
- **Post:**
  MIRCE Akademy,
  Woodbury Park
  Exeter,
  EX5 1 JJ
  UK

Papers..Call for Papers..Call for Papers...